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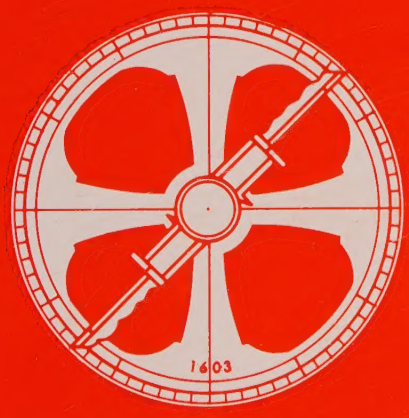


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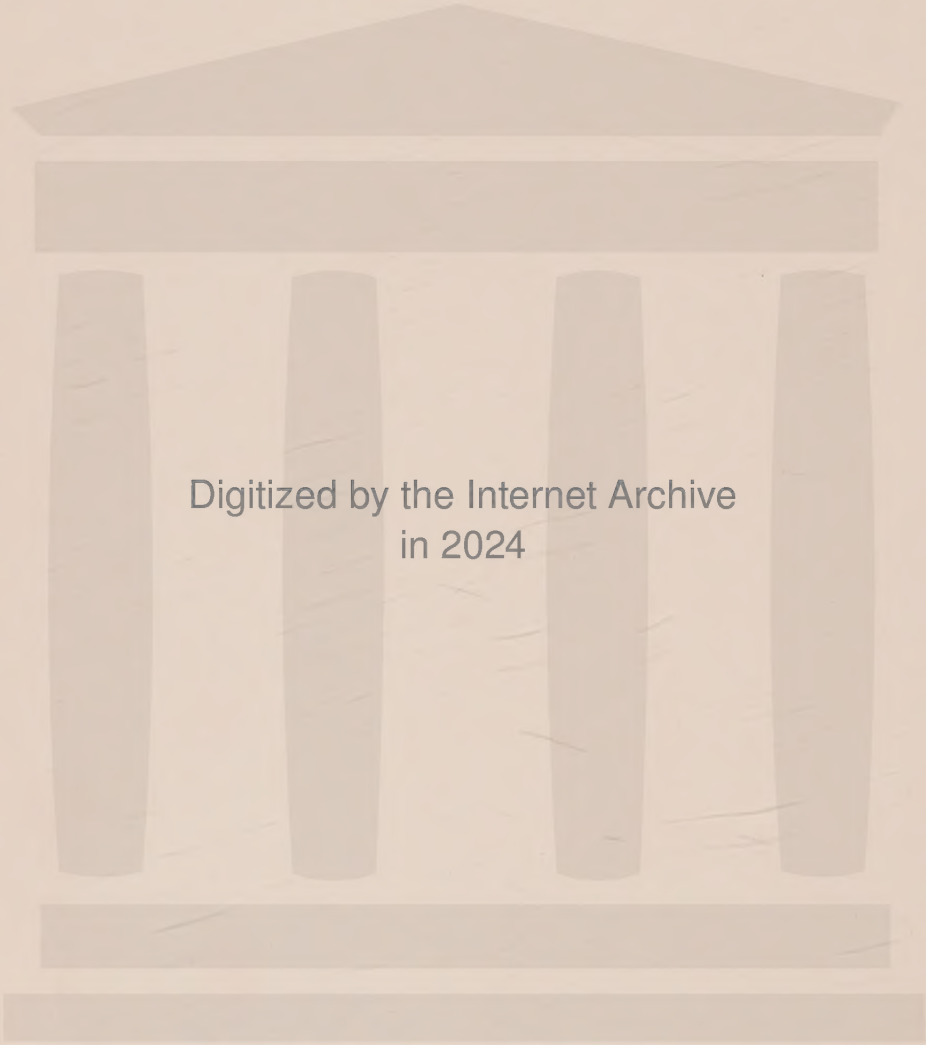
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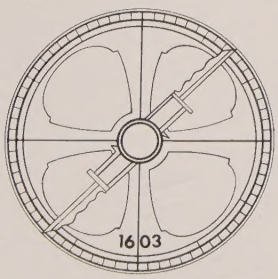
# GEOGRAPHICAL BULLETIN

*Champlain's astrolabe, lost near the Ottawa River in 1613 and found in August 1867, has been adopted as the symbol of the Geographical Branch. Appointed Geographer to the King of France in 1603, Samuel de Champlain is thus recognized as the forefather of Canadian geography.*

*The statue of Champlain stands on Nepean Point, Ottawa. The sculptor has used a degree of artistic license in that the astrolabe is held upside down.*



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GEOGRAPHICAL BULLETIN, VOL. 7, NOS. 3 AND 4, PP. 161-185, 1965

# FLOOD-DAMAGE REDUCTION IN CANADA

*Ian Burton**

ABSTRACT

In more than 200 communities floods are a constant threat to life and property. From time to time major disasters occur as in Vancouver (1948), Winnipeg (1950) and Toronto (1954). It is difficult to assess the national picture due to lack of data on flood damages. The experience of the United States and Britain suggests that flood damages may be increasing.

Four case studies (Belleville and Toronto in Ontario, Calgary and Red Deer in Alberta) are examined to show the varying types of flood problems and the ways in which they are being solved.

The report concludes that there is need for a broader attack on flood-loss reduction including flood-plain zoning, urban renewal and flood proofing as well as conventional engineering approaches. There is also need for the collection of flood-damage data and for the dissemination of information on flood hazards to planners and private citizens.

RÉSUMÉ

Dans plus de 200 collectivités, le danger d'inondation est une menace constante envers la vie des gens et leurs biens. De temps en temps une catastrophe se produit, comme à Vancouver (1948), à Winnipeg (1950) et à Toronto (1954). Il est difficile d'évaluer les dégâts à l'échelle nationale en raison du manque de données sur les inondations. Les épreuves subies par les États-Unis et la Grande-Bretagne indiquent un accroissement des dommages causés par les inondations.

L'auteur étudie quatre cas (ceux de Belleville et Toronto, en Ontario, de Calgary et de Red Deer, en Alberta) en vue d'illustrer les différentes sortes de problèmes posés par les inondations, et les diverses façons par lesquelles on peut les résoudre.

L'auteur conclut qu'il est nécessaire de s'attaquer, sur une vaste échelle, à l'atténuation des dommages causés par les inondations. Le zonage des plaines inondables, l'aménagement urbain et les mesures préventives doivent être utilisés aussi bien que les travaux habituels du génie. Il est également nécessaire de recueillir les données sur les dommages causés par les inondations et de publier à l'intention des urbanistes et du public en général les renseignements relatifs aux inondations.

## FOREWORD

This report is based on an office and library review of all readily available materials. Considerable information has also been obtained by correspondence with provincial government agencies. Interviews have been conducted in Ottawa, Quebec City, Toronto, and Winnipeg. Field work has been undertaken in Toronto and Belleville, Ontario. Nevertheless, due to limitations of time and money available it has not been possible to make a complete canvass of all information relevant to the flood problem. It has not been possible to consult information in the files of some provincial agencies. It is thought, however, that the gaps and omissions in the information presented in this report are not enough to impair seriously the value of the conclusions reached.

## DIMENSIONS OF THE PROBLEM

Almost every year the media of mass communication report in sensational fashion the damage and loss of life caused by floods somewhere in Canada. On most occasions the floods are of short duration and the area of damage is small. The headlines are soon devoted to other more

MS submitted April, 1964.

*Dr. Burton is a member of the Department of Geography, University of Toronto. He completed much of the office work for this paper while a temporary member of the Geographical Branch staff in the summer of 1963.

pressing matters and public interest and awareness rapidly recede with the flood waters.

Although in many communities floods remain a constant threat to life and property, the threat is not always recognized and is sometimes ignored. Occasionally a major flood strikes some part of the nation—as in Toronto in 1954, the Red River valley in 1950, and the lower Fraser valley in 1948. Then everyone is made aware of the power of this natural hazard and its great capacity for destruction. In the Toronto flood of 1954, 81 people were drowned (Metro. Toronto and Region Conserv. Authy., 1959). In the Red River (Winnipeg) flood of 1950, damage was very heavy,* and if a similar flood were to occur prior to the completion of the Red River floodway damage would be higher, owing to further development of the land liable to flooding. In the Fraser River flood of 1948 some 16,000 people had to be evacuated from their homes and damage has been estimated at $20 million (Fraser River Board, 1958). This figure is probably substantially lower than the actual amount of damage since it does not include damage to railway property or such indirect damages as loss of income.

Disasters such as these, involving major cities like Toronto, Winnipeg and Vancouver, lead to action, and attempts are made to prevent the occurrence of similar events in the future. At such times also, major shifts may take place in government policy. New committees and commissions are established and old ones are galvanized into fresh activity. It is an apt comment that action almost invariably follows disaster. Flood hazards are recognized in many places, but the threat often seems remote until it is too late. A common approach to flood damage has been corrective rather than preventive.

The continued occurrence of destructive floods, both large and small, provides a measure of the nation's adjustment to this environmental hazard. In spite of highly advanced engineering and communications technology, floods continue to plague us, and there are no signs of a progressive reduction of flood damages. Intelligent and informed appraisals of the problem range from the view that individual managers of flood-plain property make adjustments consistent with their own best interests and that hence human use of flood plains tends toward an economic optimum; to the notion that flood protection provided at public expense serves only to subsidize and support uses of land that are already unduly expensive.

There is no panacea. It is not possible either to prohibit Canadian citizens from developing all flood plains, or to surrender those that do take such risks to the consequences of their actions. Engineering works such as dams, dykes, and channel improvements, reduce or control flood flows in part, but do not prevent, and may even encourage, the creation of new damage potential, without providing all the security that is sometimes attributed to them. It is only rarely that dams can be built large enough to contain the largest possible floods, and such construction, even where technically feasible, is often of doubtful economic value.

The dilemma is real. For fear of flood damages of unknown extent that may come in the future, advocates of abandoning flood plains outright, or of prohibiting further development would deprive the nation of a valuable natural asset that can be used to produce income now. Human adjustment to floods is a problem calling for the exercise of a broad horizon of understanding and a high level of management skill. More of both are required, but this need not be allowed to prevent the full use of such knowledge and skill as is available.

Loss of life, the distress caused by property damage, and the suffering that results from the dislocation of the economic life of communities, are well known concomitants of a major flood. Much less well appreciated is the problem of numerous smaller floods, as for example the Timmins, Ontario, flood of 1961 (McMullen, 1962). In single cases, the loss of life, the property damage and the disruption of business are all insignificant on a national scale. Such floods are more often associated with inconvenience rather than disaster. Yet they occur often enough to constitute a significant problem for the nation if taken together. They are significant if only because they represent one way in which loss and inconvenience are consistently borne by a section of the population often least able to withstand them. Flood losses give rise to recurrent demands for public action to control floods and reduce damages. Insistent demands cannot usually be ignored indefinitely and action eventually results.

*No estimate has been made of the total direct and indirect losses in the 1950 flood, but it has been estimated that if a flood of equivalent magnitude had occurred in 1957 the damage would have totalled $114.2 million. *See* Manitoba, 1958, p. 33. Table 5–4; and U.S. Geol. Surv., 1956, p. 156.

For governments to chart an equitable course among these paths is not easy. There is no acceptable and simple view of the flood problem. While it is true that insurance companies consider floods "acts of God" that cannot be covered by most existing policies partly because they are certain to happen in areas where flood insurance is sought, it is also true that flood damages are very largely a consequence of the acts of man. More than 70 years ago the geologist WJ McGee (1891) noted that:

"the flood remains a barely mitigated evil, a hardly appreciated obstacle to progress. Indeed as population has increased, men have not only failed to achieve means for suppressing or for escaping this evil, but have, with singular short-sightedness rushed into its chosen paths."

McGee refers to man's apparent affinity for flood-plain land. Although the elements of nature are not now regarded as inherently good or evil, and although floods are not now a significant obstacle to progress, nevertheless his observation of man's attitude to the flood hazard is a fair comment on present-day human actions, even more so than in his own day.

Floods occur in a capricious, highly irregular, or random fashion. Dealing with the damaging and violent aspects of such a phenomenon is a problem of adjusting human occupancy to the flood-plain environment in such a way as to utilize its natural advantages most effectively, while at the same time doing whatever is feasible and practicable to minimize the detrimental impact of floods. Failure to do this will only serve to increase damage and suffering. It is then that acts of God are in danger of becoming human acts of criminal negligence.

In their own public decision-making, and in setting guide lines for the private decision-making of numerous individuals and corporate groups, governments tend to mitigate the apparent evil of flood damages. Yet in determining what policy to adopt no simple formula for economic optimizing is available. It is becoming increasingly fashionable to attempt to estimate the benefits and costs of flood-control schemes.* Predicting the outcome of present decisions, however, requires not only the sharp tools of economic analysis. It requires an adequate appreciation of the decision-making process, especially in the private sector, for no government policy is likely to be successful in the absence of understandings concerning the way in which flood-plain managers make their decisions and the principal factors that enter into those decisions (White, 1964).

*Benefit-cost analysis forms part of the reports by the Metro. Toronto and Region Conserv. Authy., 1958; Manitoba, 1952 and 1958; the Ausable River Conserv. Authy., 1959; the Upper Thames River Conserv. Authy., 1957, 1958, 1959 and the Moira River Conserv. Authy., 1959.

## THE NATIONAL FLOOD POLICY

It is scarcely appropriate to speak of a Canadian policy in flood-damage reduction, for with very few exceptions there are no Canadian or national flood problems in the legal sense. Under the terms of the Canadian constitution as set out in the British North America Act, as amended, and as subsequently interpreted in court rulings, the regulation of natural resource development is a provincial and not a federal responsibility. This has discouraged the federal government from taking the interest in flood problems that has now come to be expected from the United States government. The federal government can take action on all rivers deemed navigable, and on interprovincial rivers but in general has refrained from doing so. Its reluctance to becoming involved in flood problems is evidenced on the occasion of major flood disasters beyond the capacity of a provincial government to handle. For example, during the 1950 Red River flood the then Prime Minister was asked in Winnipeg if the government had formally recognized the flood as a national emergency. As reported in the *Winnipeg Free Press*, May 22, 1950, he replied,

"I do not like the words 'national emergency'. When something happens to Canadians, then all Canadians are interested. Already there is ample proof of the widespread effect upon Canadians that this flood has had."

This statement in part reflects the constitutional position described above. It also reflects the state of uncertainty exhibited by successive Canadian governments as to the appropriate role to play in the alleviation of flood problems.*

Eventually, of course, the federal government has become intimately involved in the Winnipeg flood problem and is bearing a substantial portion of the cost of building a large diversion channel

*See speech by Alistair Stewart in Hansard for May 24th, 1950. House of Commons Debates vol. 90, no. 63, Twenty-first Parliament, 2nd session. K.P., Ottawa, 1950, pp. 2083–2084.

to carry the flood waters around the eastern side of the city. This floodway is now under construction.

In the absence of a major disaster, however, flood problems remain almost entirely in provincial hands. In consequence, the attention paid to the problem varies greatly from place to place, for not only is the severity of the problem different, as is to be expected, but also the ability of the provinces to help themselves in this regard is not equal. The provincial view of flood problems differs widely—from considerable concern in some provinces to outright discounting in others, or as one official puts it: "There are no recognized flood problems in this province."

## THE UNITED STATES EXPERIENCE

Valuable insights into Canadian flood problems and policies can be gained by an examination of the American experience.

Until the present century the problem of floods in the United States was regarded primarily as a local or at most a state concern. More recently the federal government has been deeply involved. The shift in responsibility from the local to the federal level began with federal government involvement in major flood-problem areas such as the lower Mississippi, well documented by Robert W. Harrison in his *Alluvial Empire* (Pioneer Press, Little Rock, Ark., 1961). The Flood Control Act of 1936 acknowledged federal responsibility for flood control on navigable waters, and encompassed urban flood problems, while the Watershed Protection and Flood Prevention Act of 1954 broadened federal responsibility still further into the realm of floods on small watersheds in agricultural areas.

A major element in the flood-control program has been heavy reliance on engineering works such as dams, levees and floodwalls, while other possible adjustments such as land-use regulation, flood proofing, encroachment statutes, building codes and the like (White, 1945) have been little used. The engineering works constructed have been sound, and have prevented considerable damage that would otherwise have occurred. In spite of an average annual expenditure of between $300 million and $400 million on flood-control works, however, the rising toll of flood losses has not been arrested. A major reason for this is continuing human invasion of flood-plain land (White *et al.*, 1958). A recent Corps of Engineers report indicates that at the present rate of spending, flood protection will "just about keep up with the increase in flood damage that may be anticipated by 1980 as a result of the flood plain development over the next two decades" (U.S. Senate, 1960, p. 29). Under 1938 conditions, the average annual economic loss to the United States from floods was about $700 million. In 1980 it will be about $760 million, if by that time a total investment of $11.5 (1959 dollars) billion has been made in flood-control projects. The position has been aptly summarized by White and Cook (1963, p. 345) who point out that, "if future flood-control efforts are confined to the construction of engineering works, while the Nation's citizens continue to develop its flood-plains without regard for the effect on flood losses, expenditures of Federal funds will have to exceed $300 million annually, on the average, to keep flood losses from increasing. In other words, the cost to the nation of permitting uncontrolled development of flood-plain lands averages more than $300 million annually."

A rapidly expanding literature* on alternative adjustments has been accompanied by a growing realization of the need for a broader approach to flood problems. Still more knowledge is required, but at least the direction of movement is clear.

### *Application to Canada*

One simple, broad implication for Canada of this experience is clear. At a time of rapid urban growth, future flood problems may be created by unthinking invasion of hazardous areas. The large expenditures on flood control that have become necessary in the United States can still be avoided in Canada if steps are taken to ensure that development of flood-plain land, particularly in urban communities, is guided in such a way as to make maximum use of the land while at the same time exposing life and property to a minimum of risk. With carefully planned development based on sound hydrological studies this can be achieved. Undoubtedly it is being achieved in some places. But in general, urban expansion continues on the flood plains without careful study of the possible consequences. The growth of flood-damage potential in Winnipeg has

**See* Fraser River Board, 1958; White, 1945, 1961; Sheaffer, 1960; Goddard, 1961; Murphy, 1958; Tennessee Valley Authy., 1963; Burton, 1962, 1961a; Roder, 1961; Kates, 1962; Burton and Kates, 1964a and b; Sutton, 1963.

already been cited. Similar developments have been reported at Kamloops in British Columbia (Fraser River Board, 1958), and can be seen in many other cities.

## THE BRITISH EXPERIENCE

Unlike developments in the United States, flood problems in Britain are regarded primarily as a local or regional concern, not the business of the central government. Flood-control schemes are financed by regionally supported River Boards, and decisions to undertake engineering works made by the local authorities entail responsibilities for a substantial proportion of the cost. The central government participates in the financing of schemes in roughly inverse proportion to the ability of a given River Board to meet the full cost. In consequence central government assistance for flood-control work is frequently smaller in urbanized river basins such as the River Trent area, than in rural and agricultural basins such as the River Great Ouse area.

Town and country planning is also more highly developed and effective in Britain than in the United States, and local planning regulations frequently, though not always, prohibit or restrict further flood-plain development. The avoidance of flood-hazard areas has also been facilitated by a rural settlement pattern in which nucleated villages are often located on terraces above the level of the present flood plain. Modern expansion of these villages has been guided away from flood plains by careful planning (Burton, 1961b). In consequence heavy expenditures on flood control have been avoided in Britain, although the country is densely populated and heavily urbanized. Flood losses occur, but there is insufficient evidence to indicate whether they are increasing or decreasing.

In Britain, as in Canada, there are no figures of flood losses recorded on a consistent basis. In both countries, it is difficult to isolate from the expenditures of all the levels of government involved, the amount of money spent on flood-control works.

The success of the British policy, however, has been dependent, in part, on central government initiative. The closest approach to the British River Boards in Canada are the Ontario Conservation Authorities. Both are organized on a river-basin basis, their activities being controlled largely by constituent local governments that provide money in the form of a tax for most of the normal expenditures of the Boards and the Authorities. In Britain it was found necessary to make the establishment of such Boards obligatory. In Ontario this has not been considered necessary, and parts of the province still remain outside the jurisdiction of any Conservation Authority (Pleva, 1961).

### *Application to Canada*

A major implication for Canada is that heavy expenditures on flood control are not a necessary corollary of densely populated and urbanized areas. It also seems that the involvement of a national government can be avoided except in the case of the largest and most disastrous floods. When the problem is handled primarily at a local or regional level, however, it may become more difficult to integrate flood-control work with other elements of water-resource development. There is also less likelihood of collecting and recording data on trends in flood control, flood losses and flood-plain management on a national scale, thus inhibiting a nation-wide attack on flood losses.

A flood policy for Canada need not follow closely either those of Britain or the United States. It may, however, seek to profit from their experience, and then to show the way toward a more rational and effective approach. It would involve the collection of damage data on a national, standard pattern, and the analysis of this data to indicate the direction of rational solutions. The effort would require at least three steps: (1) the precise definition on maps or air photographs of areas subject to flooding, and an analysis of the hydrological characteristics of the flooding including expected depths and frequencies; (2) the collection of flood damage estimates for all floods immediately after their occurrence; and (3) a continuous monitoring of changes in flood damage potential by mapping and/or sampling land use in the areas defined under point (1) above. When more data becomes available, and when a better knowledge of flood problems than is now possible is a reality, it may, of course, prove that present arrangements are generally effective in mitigating flood losses. There is considerable circumstantial evidence that this is not likely to be the case. It is the main purpose of the remainder of this paper to establish beyond a

reasonable doubt the need for a new look at Canadian flood problems.

## TYPES OF FLOOD

Defining a flood is as difficult as mapping a flood plain. Common definitions include the notions of bank-full stage and damage stage. Bank-full stage is that elevation of a river or stream at which it begins to overflow its banks. Damage stage is that elevation at which damage begins.

At least four types of flood may be recognized according to the physical factors involved. These are:

(1) Snow-melt floods

(2) Ice-jam and ice break-up floods

(3) Convectional storm floods

(4) Cyclonic storm floods

This typology is useful because it is possible to associate certain characteristics with each, although it is an oversimplification because there are many other contributory factors, and rarely can a flood be ascribed to a single cause.

*Snow-melt floods* occur in the early spring when a winter's accumulation of precipitation may be liberated and flow off a watershed within a short period. Such floods are most likely to occur after an unusually heavy season of snowfall, and in areas where snowfall is normally heavy. They are also associated with a rapid thaw process as when the temperature rises rapidly after a long cold period and stays high for several days. The hydrograph associated with snow-melt floods often demonstrates a flat curve, and the flood-to-peak interval may last several days or even weeks. The Red River flood of 1950 is an example of a snow-melt flood. There was heavy snowfall in the winter and an above-normal accumulation at break-up. Important contributory factors were that the thaw or break-up came later than usual, the soil moisture content was high due to a wet autumn, the ground was frozen and above-normal rainfall also occurred during break-up. Ice-jams were an additional cause of flooding on a few tributaries.

At Winnipeg the river reached flood stage (746 feet) on about April 23, flood peak was in mid-May (approximately May 18) and the river did not return to below flood stage until the end of the first week in June. The flood-to-peak interval was about 25 days and a further 20 days were required for the river to drop back to flood stage (U.S. Geol. Surv., 1956).

*Ice-jam and ice break-up floods* also occur in the early spring, and are a type of flood common to most of Canada. Ice-jam floods may occur at any time during break-up and are not necessarily more likely to happen when the stage of the river is high. Such floods are more frequent when there is an abundant quantity of ice jammed together to form a temporary dam. Ice-jams notoriously occur at constriction points such as a sharp bend, a gorge or a bridge-crossing or any other physical obstacle. They may also occur where the gradient of a channel changes from steep to gentle, or at the point where a stream discharges into a lake. Other contributing factors are the thickness of the ice and the direction of the river. For example, problems may arise on north-flowing rivers such as the Red, Moose, Chateauguay and Chaudiere, where the downstream sections remain fast frozen while the upstream southern sections are in freshet. Once a jam develops the water often rises behind it very rapidly so that the hydrograph of an ice-jam flood is often much more peaked than that of a snow-melt flood.

An example of the ice-jam flood is the Belleville, Ontario flood of 1936. Belleville is situated at the mouth of the Moira River on Lake Ontario. Frequently the ice on the river goes out while the Bay of Quinte is still frozen. The ice carried by the river may then jam up against the ice on the lake, causing water to back up and flood the city.

In 1936 this type of flooding resulted in water five feet deep on Front Street. An area of 75 acres in the city was flooded, 200 people were homeless and damage was estimated at between $100,000 and $250,000. The flood was eventually brought to an end when the ice-jam was successfully dynamited. The flood lasted from March 12 to March 19, but both the rise of flood waters on the 12th and the fall on the 19th were rapid (Ont. Dept. Planning and Dev., 1950).

*Convectional storm floods* are associated with violent local storms caused by convectional flows of air. Such storms occur most frequently in summer in southern Canada and are often accompanied by thunder and lightning. They tend to be of short duration and to produce floods only in small watersheds and in urban areas when storm drains are sometimes inadequate to take large flows. The frequency of thunderstorm days has been examined by Kendall and Petrie (1962).

Rainfall probabilities in the Prairie provinces have been studied by McKay (1964).

The hydrograph for floods associated with convectional storms demonstrates a sharply peaked curve. Flood waters rise very quickly and subside equally as rapidly. The convectional storm typically lasts not more than a few hours and is usually responsible for flash floods. Basement and cellar flooding occurs every summer in many cities as a result of convection storm flooding. Frequently also highway underpasses beneath railway tracks are filled with water for short periods.

*Cyclonic storm floods* are of variable length and magnitude depending in a large part upon the nature of the storm. The rainfall associated with cyclonic storms is usually more widespread, less intense, but of longer duration than that associated with convectional storms. In consequence the rise of flood waters is slower, but larger drainage areas are more easily affected.

Although the distinction between these two kinds of storms is a useful one, floods are frequently caused when frontal activity is particularly violent and is associated with convectional currents as in the Timmins, Ontario flood of 1961. Considerable latent instability existed in the area on the day of the storm and was triggered by the passage of a weak centre of low pressure. A rainfall of eight inches fell in less than twelve hours in a very limited area around the city. This was sufficient, however, to cause the Town Creek to flood (McMullen, 1962).

The most severe cyclonic storm flood to occur in Canada this century was caused by a hurricane in 1954. Hurricanes are frequent along the east coast of the United States in late summer and early fall. Their normal course takes them from the Caribbean area where they originate, in a parabolic arc parallel to the east coast, and they eventually sweep out into the North Atlantic Ocean off New England. Infrequently they go directly north into southern Quebec or the Maritimes. A hurricane that moves further inland, however, is unusual. Such an event occurred in October 1954, when Hurricane Hazel turned across New York State and into Ontario passing over the Metropolitan Toronto area. The catastrophic effects of this storm are well known. It is an example of the violent kind of cyclonic storm, and although 32 hurricane-spawned storms are known to have occurred in Ontario since 1878 (Metro. Toronto and Region Conserv. Authy., 1959), few were as severe as Hurricane Hazel.

## HUMAN RESPONSE TO FLOODS

Most of southern Canada was settled at a time when technology was much less advanced than at present. Rivers were widely used for both transportation and power. It was therefore both natural and logical that many settlements should be located on or near rivers. The earliest settlements were located on the large rivers because these were the only available means of access to the lakes and the sea and to the market for products in the Old World. Settlement on flood plains was further encouraged where the alluvial soils of the valley bottoms was more fertile than those of the uplands. The streams themselves were also used as sources of power to turn the wheels of many grist mills.

When settlements grew larger, the streams became important sources of water in some instances, and were also a convenient means of disposing of wastes. Railway as a new form of transport served to emphasize the value of the valley floors, for they could often be most cheaply constructed by following the low gradients of the valleys. Industrial development, often associated with railway transport, took place in towns and cities and it was found that construction of large factories was easier on the level land of flood plains than on hill slopes. Low-lying land was also favoured as being cheaper to supply with water because less pumping was required.

All these advantages of river and flood-plain sites have helped to shape a distribution of settlements strongly associated with flood-hazard areas. Flood damages are the price paid for utilizing the natural advantages of the flood plain, but the comparative advantages are not so great as they once were. Smaller streams are no longer used for power or navigation, and where hydro-electric power is developed with modern technology it can easily be transported out of the flood-hazard area. Large-scale earth-moving machinery has also made it possible to create level building sites on sloping land. Under present conditions there is much less need to locate cities in the path of floods. Once a settlement has been established, however, the chances of removing it to another site are slim. The heavy investment in streets, water and gas supply, drainage, electricity and other services are not readily abandoned.

Nor are the owners of property anxious to transfer to another site at their own expense. In consequence efforts are often made to protect the settlement from floods, and when protection is provided there is added reason for expanding and developing the site. Despite the fact that modern highways are less demanding of easy gradients than were the railways, nevertheless they too tend to follow the river valleys, if only because they connect cities located in flood plains.

## FOUR CASE STUDIES

The following four cities together illustrate something of the range and variety of flood problems, and the kinds of adjustment that are being made.

Belleville, Ontario, illustrates the failure of a community to secure flood protection and the lack of other alternatives for it to turn to as a means of reducing future flood damages. Calgary, Alberta, is a city where expansion has been taking place in the flood plain in the face of a recognized flood hazard. Red Deer, Alberta, is a smaller community seeking sites for industrial expansion and turning to the flood plain for this purpose, while trying to guide development into the least hazardous sections. Toronto, Ontario, is the site of a major flood disaster that has spurred the establishment of a multi-purpose recreation and flood-control scheme.

*Belleville, Ontario*—This community has suffered from periodic ice-jam floods on the Moira River, and has recently been engaged in an attempt to gain financial assistance for the construction of a flood-protection (ice-control) dam. A brief was prepared for the Moira River Conservation Authority and submitted to the provincial and federal governments in 1958. The brief comprised a benefit-cost analysis of the proposed flood-control dam as requested by the federal government, and a request for $165,000 from each of the governments. This relatively small sum of $330,000 is 75 per cent of the total cost of the scheme. The city would be required to pay $107,800 towards the cost or 98 per cent of the balance. The remaining 2 per cent would come from other communities in the Moira watershed.

This was the latest of a series of attempts to obtain support for a flood-protection scheme for Belleville. The earlier attempts are described in a summary presented to the city of Belleville by the Conservation Authority and dated February 13, 1961. Two attempts had been made following the maximum flood on record in 1936. The extent of this flood is shown in Figure 1. The failure of these attempts by Belleville alone led to the formation of the Moira River Conservation Authority, in the hope that a more powerful and united front would prove successful. Other communities in the valley joined in the establishment of the Authority, and a third proposal presented in 1948 to the federal government was rejected on the grounds that the stream was not navigable and did not therefore qualify for federal assistance. Negotiations with both senior governments were continued sporadically without any significant progress for the next ten years. Meanwhile some work was carried out by the Authority in obtaining designs and cost estimates for the proposed dam.

The latest approach was made in 1958. The damages that would occur in the event of a repetition of the 1936 flood were measured by sending a questionnaire to 233 establishments in the flood plain. Only 79 replies were received, on which estimates for the whole study were based. As it was also estimated that construction of the ice-control dam would permit $1,095,000 of these damages to be prevented, this amount is listed as a benefit from the scheme. The proposal was rejected by the federal government, not only on the basis of the analysis which found a positive benefit-cost ratio, but because it was not considered to qualify as a major project under the Canada Water Conservation Assistance Act. Local officials in Belleville obtained the impression that it was rejected because projects of less than $2,500,000 were too small for federal government participation (personal communication). Federal officials claim that no lower limit for project cost was ever specified and that each project was considered as its application was received (personal communication).

The Authority then decided that there was little point in making further representations to the federal authorities and that the matter should be referred to Belleville for action. The city decided to consult the persons involved, and sent a letter of enquiry with a questionnaire to be completed by all residents and businessmen in the flood-prone area. The response was most discouraging. Of some 800 questionnaires distributed, only 215 were returned and of these only 60 indicated support for the city to go ahead with the scheme. Accordingly, the city drew the con-

FIGURE 1. The 1936 flood at Belleville, Ontario.

clusion that the people were not sufficiently interested in receiving flood protection and abandoned the project. Interviews conducted in the area in September 1962* revealed that many residents have little or no awareness of the flood hazard. Some did not recall the last severe flood in 1936, and among those who did, most felt that such a flood would not occur again. These residents ascribed their optimism to the very existence of the Conservation Authority and to the greater degree of preparation by the city. This latter reason is in part valid. A flood-warning system has been set up for the city in conjunction with the Moira River Conservation Authority, and Civil Defence Authorities. Preparations have also been made to meet the flood emergency should it arise, and instructions for city personnel were printed in the City Engineer's Annual Report in 1961. Nevertheless, the optimism of residents and businessmen in the flood-hazard area is not justified by the facts. A flood equal to, or greater than, the 1936 flood could occur at any time in late winter or early spring when ice is being carried downstream and conditions are right for an ice-jam to develop. The 1959 Moira River Authority brief puts the return period of the 1936 flood at 20 years. If this is a correct estimate, floods of much greater magnitude can be expected over a longer period.

The flood-warning system and the emergency measures proposed by the City Engineer would help to reduce damages when another flood comes, although considerable damage could still occur. The choice facing governments at all levels has largely been one of building the dam or doing nothing at all. While the dam was under consideration, nothing else was done, but since the final abandonment of the scheme, plans for warnings and emergency action have been formulated. However, in theory there are many other possible adjustments that could be made in Belleville. Private citizens could be informed about the nature and degree of the hazard. Many of them are now unaware of it. Technical advice could also be made available on how best to remove valuable property from the flood-hazard area, and how to make buildings themselves flood-proof. Facilities for sandbagging and other emergency measures could be kept constantly available. Some managers have made preparations to meet an emergency, among the more elaborate of which are those made by the manager of the Eaton's store on Front Street. Many others do nothing.

In addition to the planning that private citizens can initiate, there are more ambitious public alternatives. The city of Belleville has turned its back on the river. Travelling down Front Street by car the casual visitor does not suspect the existence of the river immediately behind the buildings and shops that front onto the west side. Yet the river with its rushing waters and rocky bed is one of the most attractive features of the town. Front Street is also congested, and there is a lack of public open space. There are no gardens and no places for the weary shopper to sit in the shade of trees. Nor are there adequate parking facilities for the cars that jam the main shopping area and business section.

An ambitious plan would be to attempt the phased withdrawal of all property in the central business section that lies between Front Street and the river. This would open up the city and give a broad view from Front Street across the river. Space would be created for gardens and for additional parking facilities. Small recreation facilities such as a miniature golf course might also be provided. In addition to these benefits which might revitalize the centre of Belleville, considerable reduction in future flood losses would be achieved. The plan could be carried out over a number of years, and arrangements might also be made to provide flood-plain properties with a subsidized flood-insurance program while they remain in the hazard zone. Funds for the scheme might be justified both on the grounds of flood-damage reduction and the need for urban renewal. Such an ambitious alternative is not now available to Belleville because no existing legislation provides for financing of such multi-purpose schemes. The possibility has its merits, however, and on closer examination may prove to be economically feasible. An effort to broaden the range of choice where flood protection cannot be provided would give cities like Belleville an incentive to seek alternative methods of solving the flood problem.

*Calgary, Alberta*—Calgary is located on a flood plain at the junction of the Bow and Elbow rivers. It was founded as a North-West Mounted Police fort in 1875, and the site selected for the post was a flat terrace just above the junction of the two rivers (Putnam, 1952). In 1883 the C.P.R.

*By the author with assistance from C. W. Bridge, M. A. Church, M. Foty, H. Gordon, G. J. V. Kokich, C. Louis, D. Rigby and J. Westman.

transcontinental railway reached Calgary along the flood plain of the Bow River, and the town became the major maintenance centre for the railway company in the western section of the prairie provinces (Bussard, 1935). The town grew up around the fort and railway station in the land above the confluence, and this area is now occupied by the downtown section of the city. Calgary has grown out from the centre in all directions, extending along the river valleys and also out onto the surrounding uplands. Growth has been particularly rapid since 1948, and in the period 1951–1956 the city's population increased by 42.5 per cent from approximately 140,000 to 200,000. Expansion has been conditioned by the feasibility of water and sewer line extensions, and has tended to concentrate in the flood plains, especially that of the Bow River to the southwest and southeast of the city (Smith, 1962), although the Planning Board is now making efforts to keep further development out of the flood plain.

Several major floods have occurred since the site was first settled. One in 1897 is said to have been the largest known but information on it is very slight (Hendry, 1915, pp. 30-31). A number of other damaging floods have occurred and on them the information is more complete. A summary of gauge heights and discharges for four of them is given in Table 1.

*Table 1*
*Spring floods at Calgary*[a]

| Date of flood | Gauge height (feet) | Discharge (cu.ft./sec.) |
|---|---|---|
| June 1897 | 17.52 | 99,000* |
| July 1902 | 16.7 | 90,000* |
| June 1915 | — | 41,600 |
| June 1932 | 12.5 | 53,600 |

[a]Information supplied by T. D. Stanley, Production Supt., Calgary Power Ltd.
*Estimated.

It is known that these floods were caused by sustained rainfall and in the case of three by melting snow. A repetition of either the 1897 or 1902 floods would be catastrophic, causing millions of dollars worth of damage in the Calgary area. The approximate extent of the 1897 flood is shown in Figure 2. A small measure of alleviation is afforded by storage reservoirs on upper tributaries which may be expected to reduce a flood of the magnitude of the 1902 flow in the order of 20 per cent. Land fill in various parts of the flood plain would reduce flooding in these places but cause higher stages elsewhere. Little information is available on rainfall in the watershed at the time of these floods, except that the 1932 flood is known to have been caused by rain concentrated mainly in the foothills and east of the second range of the RockyMountains (i.e., below Banff).

The highest flow on record for the Elbow River, 26,000 cfs, also occurred in 1932. A limited measure of control is provided by the Glenmore Dam (built mainly for water-supply purposes) but a repetition of the 1932 flow would cause considerable damage in the residential area from the dam to the Bow River confluence. By fortunate chance the Glenmore Dam had just been completed in 1932 and the reservoir was being filled at the time of the flood (A. H. Nicholson, City Engineer, Calgary, personal communication).

In more recent times comparatively minor flooding has been caused by ice-jams during severely cold periods. Inundations by back-up water behind ice-jams have been controlled by the construction of dykes along both banks of the river in affected areas. The dykes are only located, however, in the central portion of the city upstream from the Pearce Estate. No protection is provided by dykes for the predominantly industrial section in the Inglewood area. The elevations of four recent winter floods are given in Table 2.

*Table 2*
*Some winter floods at Langevin Bridge, Calgary*[a]

| Date of flood | Gauge height (feet) |
|---|---|
| January 14, 1948 | 12.1 |
| December 16, 1949 | 10.9 |
| December 1, 1950 | 15.3 |
| December 19, 1951 | 13.4 |

[a]Information supplied by T. D. Stanley.

The dykes would probably contain safely a flow of 50,000 cfs but any future flood of 70,000 cfs or more would undoubtedly result in severe property damage from Bowness to the south city limit (T. D. Stanley, personal communication). A recurrence of the estimated 99,000 cfs discharge of 1897 would not necessarily follow

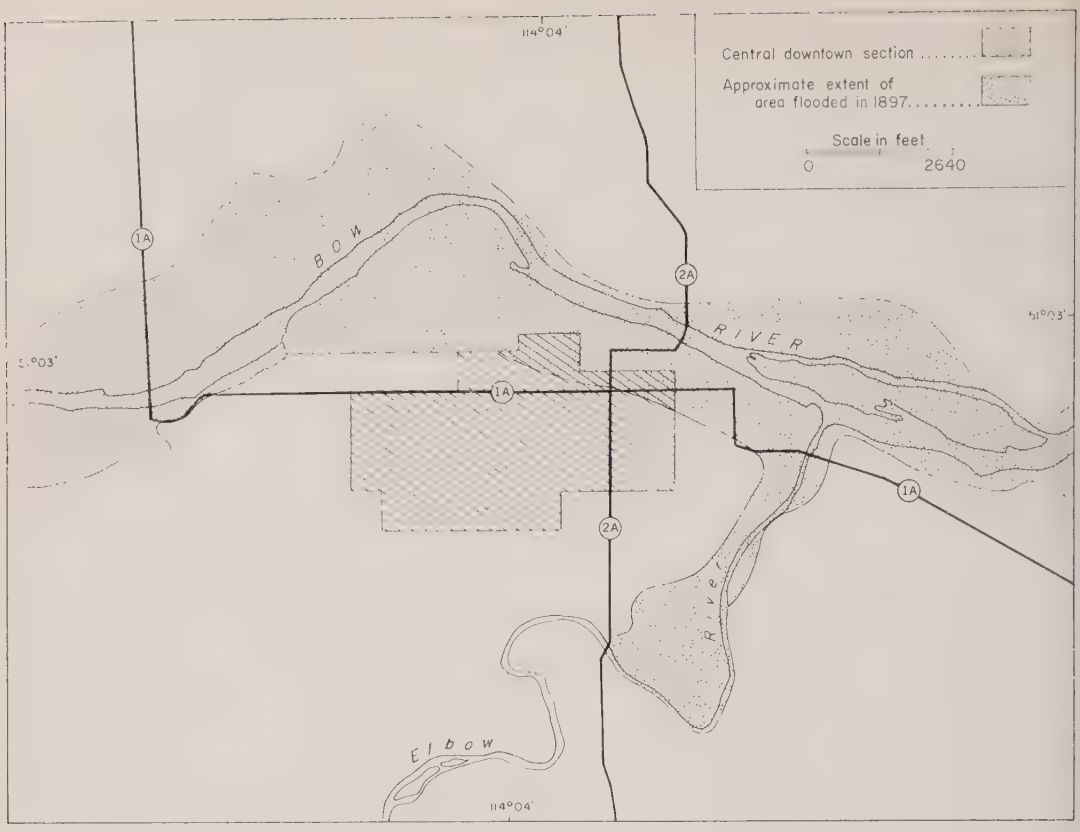


FIGURE 2. The 1897 flood at Calgary, Alberta.

exactly the same pattern of flooding indicated in Figure 2. Dyking and land fill would result in some areas then flooded remaining dry. This would have the effect of raising stages elsewhere so that areas unaffected in 1897 could well be flooded by a future discharge of like magnitude.

There is also the possibility of floods greater than that of 1897. The probability of such a flood occurring in any one given year is low. At some time in the future, however, such a flood is certain to occur.

The absence of severe summer flooding in the Calgary area for many years, and the recurrence of less severe winter flooding caused by ice jamming has led to much greater attention being given to the latter—the lesser danger of the two. Winter floods, as indicated in Table 2, are of a lower order of magnitude than late spring floods.

More than a decade ago an Alberta Royal Commission was established to examine the cause of flooding in the Bow Valley. The Commission devoted its report primarily to a consideration of winter flooding. A careful analysis was made of the available evidence, and the Commission was able to conclude that "while the complete solution to the problem has not yet been found, worthwhile advance in knowledge and experience has been gained" (Alberta, 1953).

One recommendation of the Royal Commission was that the Bearspaw power development should be constructed as soon as possible since it offered the most important single solution to ice jamming and flooding in the Calgary-Bowness area. This has now been constructed but has not solved the winter ice-packing problem. By reduction of the length of open ice making the river upstream of the area subject to ice packing it has reduced the incidence, but not the severity, of the problem. Dykes have been constructed by the provincial government since 1952 to a stage equivalent to gauge height 17 feet at Langevin Bridge. These dykes are now the main and most effective means of preventing surface flooding in the affected part of the city.

Other recommendations of the Royal Commission were: the establishment of a Bow River

Control Board to deal in an advisory capacity with the question of flood control, seepage and remedial measures; the elevation of the Bowness steel bridge to a suitable height to prevent its loss or damage by ice jamming; the extension of dykes in Calgary and cribbing or dyking in places in the Bowness area; consideration to be given to increasing the height of the present dykes to take care of high spring or summer floods; further investigation into the seepage problem; and draining down of water level in storage dams when severe snow-melt floods are expected, under the direction of the proposed Bow River Control Board.

One other recommendation of the Royal Commission is of particular importance. It was recommended that legislation be passed to,

"(a) prevent settlement or building on areas which in the opinion of authority are subject to serious danger from flooding;

(b) to cause to have buildings removed from critical areas where reasonable protection cannot be provided."

This recommendation stems from the Royal Commission's finding that, "The whole question of allowing buildings to be built in critical flood areas is alarming, not only on the Bow River but elsewhere in Canada and the United States." A comparison of two air photographs taken in 1926 and 1949 respectively shows that, "in 1926 there were less than a dozen buildings situated near the banks of the Bow River in the Bowness area, while in 1949 almost the whole area has been built up. Some of these buildings have been built on areas where incipient ice jamming or spring or summer floods occur which can cause serious damage. This is especially true of Bow Crescent and a portion of Bowness."

Calgary provides evidence from an official source that urban development of flood plains has been taking place rapidly in the face of known flood hazard, but without careful study as to the likely, or possible, consequences of such development. Here is a case where flood problems of the future are in the course of creation. Some steps are now being taken to arrest further growth of the problem. The Alberta Water Resource Act Amendment of 1960 gives the Minister the necessary authority to prevent development of floodplain lands. These powers are being used and permission has been refused for the building of a hospital and two subdivisions. A problem still remains, however, and is likely to continue at least until there is another major flood. Then demands will be placed on government authorities to provide some flood protection. Whether such protection is or will become economically justifiable is not known. To the extent that present attempts to limit further development are successful and to the extent that some damage potential is created will depend upon the amount of benefits to be derived from further flood protection. Surely the important point is that developments have been taking place under conditions of ignorance as to their possible consequences. A more rational approach would be to attempt to weigh the comparative value of the flood plain as a site for development, against the risks being taken.

*Red Deer, Alberta*—The city of Red Deer is located on the flood plain of the Red Deer River, close to the point where it is crossed by the main railway line from Calgary to Edmonton. The main part of the city lies below the bluff of a former meander scar on the southeast bank of the river. There is a small community on the northwest side of the crossing, and in recent years the city has expanded both along the flood plain and on to the top of the bluff.

The valley is subject to ice-jam floods during the winter months, and snow-melt floods in spring and early summer especially when a rapid thaw is associated with heavy and persistent rainfall.*

The highest stage recorded due to ice-jams was in 1943. The highest summer flood stage was in 1915. Details of these and other floods are given in Table 3.

The flooding has occurred mostly in floodplain reaches above and below the city, and in areas peripheral to it. The 1913 flood was dangerous but did not prove disastrous. The water rose 14 feet and was reported by the *Red Deer Advocate* (April 11, 1913) to be at its highest since the flood of 1901 when a new bridge was washed out. Ice from Waskasoo Creek (a small tributary that occupies, in part, the former course of the Red Deer in its abandoned meander southeast of the centre of the city) jammed at the Gaetz Avenue bridge, and the next bridge upstream.

**See* the report to the city of Red Deer prepared by Hadin, Davis and Brown (Alberta) Ltd., and H. G. Acres and Co., 1960.



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*Table 3**
*Selected flood stages and discharges at Red Deer*

| Ice-jams | | | Summer floods | | |
|---|---|---|---|---|---|
| Date | Peak stage (a) | Daily discharge (b) | Date | Peak stage (a) | Daily discharge (b) |
| April 8, 1913 | 17.86 | 4,000 | June 28, 1915 | 19.05 | 56,000 (68,250 peak) |
| April 7, 1925 | 17.46 | 10,600 | June 2, 1923 | 14.51 | 34,800 |
| April 4, 1943 | 21.95 | 9,690 | June 4, 1929 | 14.23 | 34,200 |
| April 7, 1955 | 18.40 | 12,000 | June 24, 1952 | 14.82 | 37,900 |
| April 8, 1958 | 15.36 | 3,110 | August 26, 1954 | 16.70 | 42,620 |

*SOURCE: Hadin, Davis, and Brown report (1960).
(a) Feet on the gauge.
(b) Cubic feet per second.

Ice-jams in Waskasoo Creek almost caused water to flood into Holt Avenue (52nd Avenue), and jams at the bridge on Gaetz Avenue caused water to flow over the concrete wall along Gaetz Avenue in one place. At a subsequent meeting of the Council, Town Commissioner Stephenson advised the Council that a recent *Calgary Herald* report of April 9, 1913, concerning ice-jam flooding and flooding along creeks was sensational exaggeration which if not stopped might cause cancellation of all insurance policies in the city.

The flood in June, 1915 was described by the *Red Deer Advocate* as the highest flood in 30 years. The Clearwater bridge two miles east of the city was washed away and other minor property damage resulted. The approximate area flooded in 1915 is shown on Figure 3.

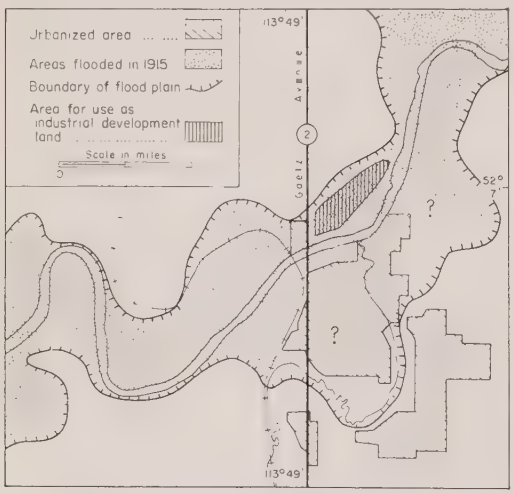
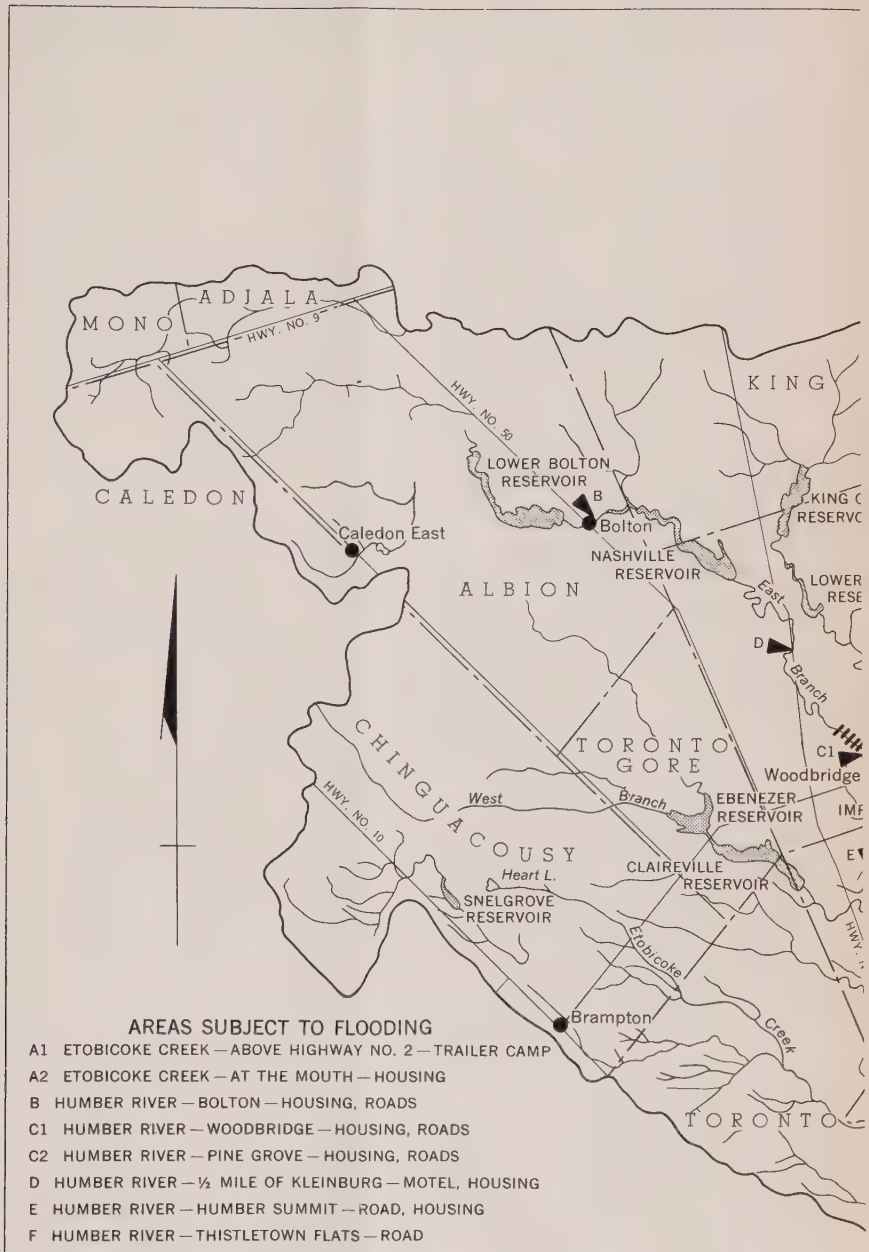



FIGURE 3. The 1915 flood at Red Deer, Alberta.

Perhaps the worst flood on record is that of April, 1943, which was described by the *Red Deer Advocate* as doing thousands of dollars worth of damage. The Red Deer River rose more than 15 feet in less than one hour about 4 a.m. The ice-jam broke at 6 p.m. and the water fell eight feet in one hour. People living on the west side of the river had hardly time to get out of their houses before the water rushed in. Some heavy losses were reported. One farmer lost 90 head of cattle, 17 hogs, a team of horses and 40 sheep. His loss was estimated at $12,000 to $15,000. A number of houses were flooded to depths of 18 inches.

Five deaths were attributed to the ice-jam flood of March 26, 1947 in Red Deer. This flood made the people of Red Deer more aware of the hazards, so that a firm of consulting engineers was engaged to advise what flood-plain land could reasonably be used for industrial development. They reported in 1960 to the city of Red Deer that there were two separate land areas on the flood plain usable for industrial development, and that each could be enlarged considerably by land filling and berm construction (Hadin, Davis and Brown, 1960). One area recommended for use is shown in Figure 3. The report does not describe in detail the calculations upon which these recommendations were based, but the suggested fill and berm construction is considered protection for the areas recommended for development from floods of a 200-year frequency. Such a flood has not occurred in the period since the establishment of the city. The summer flood of 1915 has an estimated frequency




AREAS SUBJECT TO FLOODING

A1 ETOBICOKE CREEK — ABOVE HIGHWAY NO. 2 — TRAILER CAMP
A2 ETOBICOKE CREEK — AT THE MOUTH — HOUSING
B HUMBER RIVER — BOLTON — HOUSING, ROADS
C1 HUMBER RIVER — WOODBRIDGE — HOUSING, ROADS
C2 HUMBER RIVER — PINE GROVE — HOUSING, ROADS
D HUMBER RIVER — ½ MILE OF KLEINBURG — MOTEL, HOUSING
E HUMBER RIVER — HUMBER SUMMIT — ROAD, HOUSING
F HUMBER RIVER — THISTLETOWN FLATS — ROAD
G HUMBER RIVER — WESTON FLATS — SEWAGE PLANT, ARENA, ROAD
H HUMBER RIVER — EDENBRIDGE DRIVE — HOUSING (3)
I HUMBER RIVER — BLACK CREEK — JANE ST. FLATS — HOUSING, ROADS
J HUMBER RIVER — BLACK CREEK — HUMBER BLVD. — HOUSING
K MIMICO CREEK — ROYAL YORK ROAD — HOUSING, ROAD
L DON RIVER — YORK MILLS — ROADS, HOUSING
M DON RIVER — POTTERY ROAD — ROADS, RAILWAY
N DON RIVER — BEECHWOOD DRIVE — C.N.R., INDUSTRY, ROADS
O DON RIVER — DON MILLS ROAD — ROAD
P HIGHLAND CREEK — "THE WILLOWS" — HOUSING
Q HIGHLAND CREEK — FLATS BELOW NO. 2 HWY., HOUSING, ROADS
R ROUGE RIVER — MARKHAM,
S ROUGE RIVER — ROUGE VALL
T ROUGE RIVER — RIVERCOUR
U DUFFIN CREEK — GOODWOOI
V DUFFIN CREEK — ELIZABETH
W DUFFIN CREEK — NO. 2 HWY

FIGURE 4. Metropolitan Toronto and Region

VINEGAR HILL — ROAD
EY INN — HOUSING
T DRIVE — HOUSING
) — PUMPING STATION
ST., RIVERSIDE DRIVE — HOUSING
. AREA — ROADS, HOUSING

After
"Areas subject to flooding" by Metropolitan Toronto and Region Conservation Authority.

Proposed Reservoirs .....
Channel Improvements .....
Areas subject to flooding .....

Scale In Miles
0 2 4 6 8

Conservation Authority: proposed reservoirs and channel improvements.

of once in 50 years, or more correctly, one chance in 50 that it will occur in a given year. Estimates of the frequency of the same flood by others (Hadin, Davis and Brown, 1960), range from 1 in 40 to 1 in 135. The recommendations made, are therefore on a design flood of elevation 24 feet on the gauge (compared with 21.95 feet for the highest recorded stage in 1943) or an elevation of 2,806 feet above sea level, which has an estimated frequency of 1 in 200. Extrapolations of the frequency of high discharges are notoriously uncertain, however, and clearly a flood of much higher proportions than those previously experienced is possible. Virtually the whole of the city of Red Deer lies below 2,820 feet, so that the possibility of a super-flood occupying the whole of the valley floor and flooding all property, some to a considerable depth, cannot be ruled out.

It is not clear, therefore, whether further development of the flood plain by industrial users is desirable. The recommendations made by the consultants meet with the terms of reference given to them by the city of Red Deer. It is assumed that the risk of less than 1 in 200 is low enough to be worth taking. While it is impossible to measure this degree of risk with great precision, it should be possible to assess the benefits of developing flood-plain land instead of using higher land not subject to floods. There is no acute shortage of suitable nonflood-plain land around the city of Red Deer.

The city of Red Deer presents a problem distinct from that of Calgary. Here the city government has determined upon expansion in the flood plain as a matter of policy and has been quite precise about the level of risk to be taken. A basis for evaluating the policy will be lacking, however, until the value is known of the benefits that accrue from use of flood plain rather than upland. This value may never be known.

*Toronto, Ontario*—The flood-control project for Metropolitan Toronto currently under construction provides an example of a way in which flood-damage reduction may be combined with other goals into a multi-purpose project. It also illustrates only cursory consideration of alternative methods of damage reduction.

As at Belleville, a benefit-cost study was made. In the Toronto case, it was successful and the project was approved by the provincial and federal governments (Metro. Toronto and Region Conserv. Authy., 1950). Contrary to the theoretical objective of benefit-cost analysis—the evaluation of alternatives*—the technique was used to justify a previously designed project (Burton, 1965).

The background to the present Toronto plan also illustrates one of the consequences of the prevailing national flood policy. In the absence of a required systematic study of potential flood problems, little is done until a disaster has occurred. Even where floods are known to have taken place in the past, there is a tendency to assume that they will not come again. In 1950 the Don Valley Conservation Authority in Toronto published the following statement:

> On the whole the floods of the Don now do only a small amount of damage compared to those before 1880 and there seems little likelihood that the amount will increase. Flooding is not a very serious problem on the Don and does not call for costly measures of control (Ont. Dept. Planning and Dev., 1950, p. 19).

Four years later the catastrophic flood associated with the passage of Hurricane Hazel caused considerable property damage in the Toronto area (including an estimated $3.5 million in the Don Valley alone) and resulted in the loss of 81 lives. Five years later in 1959 a *Plan for Flood Control and Water Conservation* for the Metropolitan Toronto area was presented to the federal government. The plan set out in part that:

> It is the purpose of this plan to point out the urgent need for flood control and water conservation measures, to outline a program of proposed measures and to analyze the engineering, economic and social aspects of the proposed program. The Metropolitan Toronto and Region Conservation Authority respectfully requests financial assistance from the Governments of the Dominion of Canada and the Province of Ontario in respect of an integrated flood control and water conservation Program for Metropolitan Toronto and Region (Metro. Toronto and Region Conserv. Authy., 1959).

It is widely acknowledged that Hurricane Hazel (1954) changed views of flood problems in Toronto and southern Ontario. By this time (1959) the Don Valley Authority had merged with several other authorities into the Metropolitan Toronto and Region Conservation Authority to present a united front on the flood problem.

The 1959 request was for contributions of $12,795,488 each from federal and provincial

*See* Sewell *et al.*, 1962; Inter-agency River Basin Committee, 1950 and Hufschmidt *et al.*, 1961.



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governments. However, this request was not entirely or even largely for flood-control measures. As indicated in Table 4 only 22 per cent of the benefits were for flood damage reduction and over 40 per cent were derived for public recreation.

*Table 4*

*Tangible benefits of the Metropolitan Toronto plan*[a]

| Type of benefit | Value of benefit[b] | Per cent |
|---|---|---|
| Flood-damage reduction | $12,447,000 | 22.4 |
| Recreational use of reservoirs | $21,203,000 | 37.6 |
| Indirect benefits | $ 9,335,000 | 16.5 |
| Others (including water supply, fishing outside reservoirs, pollution abatement, and recreational use of acquired flood-plain lands) | $13,240,600 | 23.5 |
| Total | $56,225,600 | 100 |

[a]Derived from *Plan for Flood Control and Water Conservation*, Metropolitan Toronto and Region Conservation Authority, Woodbridge, Ontario, 1959.

[b]Figures expressed in present value, assuming a 100-year life of construction works and an interest rate of 4 per cent.

On close examination it appears likely that the Hurricane Hazel flood had the effect of generating activity and concern that will eventually lead to the provision of excellent public recreation facilities for Toronto. Government approval and funds have been forthcoming and a series of dams is to be built around the periphery of the Metropolitan area, and the lakes developed for public recreation. Construction is already under way. The location of the proposed reservoirs is shown in Figure 4.

The opportunity to develop public recreation may have helped to direct attention away from a consideration of alternative adjustments to floods. Some of these alternatives seem, on the grounds of circumstantial evidence, to offer substantial prospect of considerable reduction in flood losses without the large-scale costs of dam construction. The total area of developed flood-plain land is small, due to the ravine-like nature of the major valleys. Main lines of communication pass over the ravines on viaducts, and residential development in general stops short at the top of the valley walls. In a few places where the valleys open out to enclose wider expanses of flood plain, especially in their lower courses, there are both industrial and residential properties. These are the exception rather than the rule. Even in those places where the flood plain is crowded with development, the total area subject to flooding is relatively small.

It might be objected that if flood-damage potential is so small, it would not have been possible to justify the dams in a benefit-cost analysis. In fact this is the case. There are insufficient flood-control benefits, and it is only by adding a considerable sum of recreation and other benefits that the Toronto scheme has been justified.

What might an alternative plan have included? Since the total amount of flood-plain property is small in relation to the size and wealth of the city, a scheme involving removal of buildings from the hazard area in a program of phased withdrawal should be possible. This could be accompanied by flood-proofing measures, and an improved flood-forecasting system for those properties that remain temporarily in the flood-plain. Many of the present buildings in the flood-hazard area are old and in any case would be due for reconstruction in the next decade or so. A government sponsored insurance scheme might also be offered to those remaining on condition that they agree to evacuate by a certain date. The plan does include provision for flood forecasting and some flood-plain land acquisition, but these were not regarded as elements in a comprehensive approach to flood-damage reduction.

The architects of the Toronto plan may legitimately claim that such alternatives were not open to them. The necessary legislation, the necessary administrative and financial arrangements are all lacking, and in any case the alternatives suggested would not help in providing badly needed public recreation facilities. The point here is not that the Toronto plan is a bad one. It is not. The issue is simply that it may not be the best alternative, and that the pre-project planning studies did not consider other schemes. Had other choices been open to them, the resultant plan might have been very different and the cost to the nation much less.

## PLACES WITH POTENTIAL FOOD PROBLEMS

In an attempt to assess the magnitude of the problem a survey was made, province by prov-

POPULATED PLACES
WITH
POTENTIAL FLOOD PROBLEMS
Under 10,000 ..... Courtenay
10,000–99,999 ..... Moose Jaw
100,000–499,999 ..... Edmonton
500,000–999,999 ..... VANCOUVER
1,000,000 and over ..... TORONTO
Scale in miles
0 50 100 200
125°
115°
50°
Peace River
Terrace
Skeena R.
BRITISH
COLUMBIA
François Lake
Nechako River
Ootsa Lake
Eutsuk Lake
Prince George
McGregor R.
Fraser River
Smoky River
High Prairie
W. Prairie R.
Lesser Slave Lak
ALBE
Athabasca
Whitecourt
McLeod River
Quesnel
Quesnel R.
Fraser River
Thompson River
Columbia
Adams Lake
Shuswap Lake
Golden
Bow
Canmore
Bridge R.
Thompson R.
North
Kamloops
Nicola R.
Merritt
Upper Arrow Lake
Okanagan Lake
Lower Arrow Lake
Kootenay Lake
Penticton
Okanagan R.
Castlegar
Trail
VANCOUVER ISLAND
Campbell River
Courtenay
Alberni
Port Alberni
VANCOUVER
North Vancouver
Port Coquitlam
Mission City
New Westminster
Chilliwack
Lake Cowichan
Duncan
Sidney

105°
ALASKA
Aklavik
Fort McPherson
Peel River
Mackenzie River
Amundsen Gulf
Coronation Gulf
Great Bear L
Coppermine R
Norman Wells
Fort Norman
YUKON TERRITORY
Great Slave L
Hay River
Hay R
miles
0 100 200 300
SASKATCHEWAN
MANITOBA
The Pas
Saskatchewan R.
Carrot River
Prince Albert
Red Deer R.
Lake Winnipegosis
Lake Winnipeg
Saskatchewan River
North Battleford
Saskatoon
Assiniboine River
Valley R.
Dauphin
Lake Manitoba
50°
Qu' Appelle River
Regina
Moose Jaw
Moose Jaw Cr.
Swift Current
Swiftcurrent Cr.
Medicine Hat
Weyburn
Souris River
Estevan
Brandon
Portage la Prairie
Winnipeg
St. Boniface
St. James
Niverville
Otterburne
Union Point
Morris
East Kildonan
West Kildonan
Red River
U. S. A.
105°

od problems.

ince, to compile a list of places with a potential flood hazard. The places are listed in Table 5 and their distribution is mapped in Figures 5a and 5b. The inclusion of a place in the list does not necessarily mean that its flood problem is *officially* recognized. Conversely, the list is not comprehensive, and the exclusion of a place from the list does not mean that it necessarily has no flood problem. It has not been possible to include any meaningful estimate of the magnitude of potential damage in each place. A crude indication would be the amount of developed land on the flood plain. This may not be related in any way to the total size of the city.

There are probably about 200 places in Canada with potential flood problems. If the question were extended to rural areas and very small settlements the number would increase sharply. In general, the list has been confined to places with a population of more than 1,000.

*Table 5*
*Places with potential flood problems*

| Place | River | Population in 1961 |
|---|---|---|
| *Alberta* | | |
| Calgary | Bow and Elbow | 279,062 |
| Canmore | Bow | 1,736 |
| Drumheller | Red Deer | 2,931 |
| Edmonton | North Saskatchewan | 337,588 |
| Fort McMurray | Athabasca and Clearwater | 1,186 |
| High Prairie | West Prairie | 1,756 |
| High River | Highwood and Little Bow | 2,276 |
| Lethbridge | Oldman | 38,314 |
| Medicine Hat | South Saskatchewan | 26,705 |
| Red Deer | Red Deer | 21,107 |
| Whitecourt | Athabasca and McLeod | 1,054 |
| *British Columbia* | | |
| Alberni | Kitsucksus Creek | 4,616 |
| Campbell River | Campbell | 3,737 |
| Castlegar | Columbia | 2,253 |
| Chilliwack | Fraser | 8,259 |
| Courtenay | Tsolum | 3,485 |
| Duncan | Cowichan | 3,726 |
| Golden | Kicking Horse | 1,776 |
| Kamloops | South Thompson and Thompson | 10,076 |
| Lake Cowichan | Cowichan Lake | 2,149 |
| Merritt | Nicola and Coldwater | 3,039 |
| Mission City | Fraser | 3,251 |
| New Westminster | Fraser | 33,654 |
| North Vancouver | small streams | 23,656 |
| North Vancouver (district) | | 38,971 |
| Penticton | Penticton and Ellis Creeks | 13,859 |
| Port Coquitlam | Coquitlam | 8,111 |
| Coquitlam (district) | Coquitlam | 29,053 |
| Prince George | Fraser and Nechako | 13,877 |
| Quesnel | Fraser and Quesnel | 4,673 |
| Sidney | tidal | 1,558 |
| Surrey (district) | Nicomekkl and Serpentine | 70,838 |
| Terrace | Skeena and tributary | 4,682 |
| Trail | Columbia | 11,580 |
| Vancouver | Fraser | 384,522 |
| West Vancouver (district) | small streams | 25,454 |
| *Manitoba* | | |
| Brandon | Assiniboine | 28,166 |
| Dauphin | Vermilion | 7,374 |
| East Kildonan | Red | 27,305 |

(Continued over page)

*Table 5*—continued
*Places with potential flood problems*

| Place | River | Population in 1961 |
|---|---|---|
| Morris | Red | 1,370 |
| Portage la Prairie | Assiniboine | 12,388 |
| St. Boniface | Red | 37,600 |
| St. James | Assiniboine | 33,977 |
| The Pas | Saskatchewan | 4,671 |
| West Kildonan | Red | 20,007 |
| Winnipeg | Red and Assiniboine | 265,429 |
| *New Brunswick* | | |
| Edmundston | Saint John | 12,791 |
| Fredericton | Saint John | 19,683 |
| Moncton | Petitcodiac | 43,840 |
| Sackville | Tantramar | 3,038 |
| Woodstock | Saint John and Meduxnekeag | 4,305 |
| *Newfoundland* | | |
| *Nova Scotia* | | |
| Bedford | Sackville | 2,855 |
| Bible Hill (Truro) | Salmon | 2,415 |
| Kentville | Cornwallis | 4,612 |
| Middleton | Annapolis | 1,921 |
| Oxford | Philip | 1,471 |
| Stellarton (New Glasgow) | East River of Pictou | 5,327 |
| Truro (Onslow) | North River | 12,421 |
| *Ontario* | | |
| Ayr | Nith | 1,016 |
| Belleville | Moira | 30,655 |
| Brampton | Etobicoke Creek | 18,467 |
| Brantford | Grand | 55,201 |
| Chatham | Thames | 7,109 |
| Delhi | Big Creek | 3,427 |
| Dundas | Spencer Creek | 12,912 |
| Dunnville | Grand | 5,181 |
| Durham | Saugeen | 2,180 |
| Exeter | Ausable | 3,047 |
| Fort William | Neebing | 45,214 |
| Galt | Grand | 27,830 |
| Guelph | Grand and Speed | 39,838 |
| Hanover | Saugeen | 4,401 |
| Heathcote | Beaver | 4,040 |
| Hespeler | Speed | 4,519 |
| Ingersoll | Thames | 6,874 |
| Listowel | Maitland | 4,002 |
| London | Thames (north and south branches) | 169,569 |
| Long Branch | Etobicoke Creek | 11,039 |
| Meaford | Bighead | 3,834 |
| Milton | Oakville Creek | 5,629 |
| Mitchell | Thames | 2,247 |
| Newmarket | Holland | 8,932 |
| Napanee | Napanee | 4,500 |
| Owen Sound | Sydenham and Pottawatomi | 17,421 |
| Paris | Nith | 5,820 |
| Parkhill | Parkhill Creek | 1,169 |
| Pickering | Duffin Creek | 1,755 |
| Port Elgin | Saugeen | 1,632 |
| Port Stanley | Kettle Creek | 1,460 |
| St. Mary's | North Thames | 4,482 |
| Preston | Speed | 11,577 |

*Table 5*—concluded
*Places with potential flood problems*

| Place | River | Population in 1951 |
|---|---|---|
| Sarnia | St. Clair | 50,976 |
| Simcoe | Lynn | 8,754 |
| Southampton | Saugeen | 1,818 |
| Sudbury | Junction Creek | 80,120 |
| Tillsonburg | Big Otter Creek | 6,600 |
| Timmins | Town Creek | 29,270 |
| Toronto | Don, Humber, Rouge, Etobicoke Creek and Duffin Creek | 672,407 |
| Val Caron | Whitson | 1,751 |
| Walkerton | Saugeen | 3,851 |
| Windsor | Detroit | 114,367 |
| Wingham | Maitland | 2,922 |
| Woodstock | Thames | 20,486 |
| *Prince Edward Island* | | |
| *Quebec* | | |
| Amos | Harricanaw | 6,080 |
| Arvida | Saguenay | 14,460 |
| Beauceville | Chaudière | 1,645 |
| Bromptonville | Saint-François | 2,726 |
| Charny | Chaudière | 4,189 |
| Châteauguay | Châteauguay | 7,570 |
| Drummondville | Saint-François | 27,909 |
| East Angus | Saint-François | 4,756 |
| Lennoxville | Saint-François | 3,699 |
| Maniwaki | Gatineau | 6,349 |
| Matane | Matane | 9,190 |
| Montreal | Prairies (des) | 1,191,062 |
| Montreal (south shore) | St. Lawrence | 92,787 |
| Montreal (Île Jésus) | Prairies (des) | 124,741 |
| Richmond | Saint-François | 1,215 |
| Roxboro | Prairies (des) | 6,298 |
| Saint-Georges | Chaudière | 4,082 |
| Saint-Hyacinthe | Yamaska | 22,354 |
| Saint-Joseph-de-Beauce | Chaudière | 2,484 |
| Sainte-Marie | Chaudière | 3,662 |
| Sainte-Martine | Châteauguay | 1,695 |
| Saint-Raymond | Sainte-Anne | 3,931 |
| Sherbrooke | Saint-François | 66,554 |
| Trois Rivières | Saint-Maurice | 53,477 |
| Vallée Jonction | Chaudière | 1,405 |
| Windsor Mills | Saint-François | 6,589 |
| *Saskatchewan* | | |
| Estevan | Souris | 7,728 |
| Moose Jaw | Moose Jaw Creek and Thunder Creek | 33,206 |
| North Battleford | North Saskatchewan | 11,230 |
| Prince Albert | North Saskatchewan | 24,168 |
| Saskatoon | South Saskatchewan | 95,526 |
| Swift Current | Swiftcurrent Creek | 12,186 |
| Weyburn | Souris | 9,101 |
| *Territories* | | |
| Aklavik | Mackenzie | 599 |
| Fort Norman | Mackenzie | 189 |
| Fort McPherson | Peel River | 509 |
| Hay River | Hay River | 1,338 |
| Norman Wells | Mackenzie | 297 |

The list of places with potential flood problems is impressive for a country with a relatively small population. It suggests the need for more knowledge about flood damages. In recent years urban settlements have been expanding at a very rapid rate. There is evidence that at least some of this expansion has occurred in flood plains. Is it possible therefore, that flood damages are increasing? There is no reliable evidence on this point. No figures are collected on national flood losses and although there are some data on losses from particular floods for some provinces, there is no attempt anywhere systematically to collect data on damage from all floods. Nor would it be a simple task to break down federal, provincial and local expenditures in order to find how much the nation spends on flood control. It is therefore impossible to say with certainty what the position is. On the basis of such circumstantial evidence as the spread of urban development into flood plains, and by comparison with the United States and Britain, it seems likely that flood-damage potential is increasing.

## THE CHOICE OF ADJUSTMENTS

There is a wide range of theoretical possibilities for flood-damage reduction. Many of these were described by White (1945), and since then the choice has been elaborated by many students of flood problems (Tennessee Valley Authy., 1963). A convenient chart in use by the Tennessee Valley Authority presents a framework of many of the alternatives, and is reproduced in Figure 6.

As shown in the Belleville and Toronto cases, not all of these alternatives may be open to selection by the decision makers involved, even if they are aware of the theoretical choice. An examination of flood problems across Canada shows that where action has been taken it usually consists of some type of flood control.

### *Methods in common use*

There are extensive dykes on the lower Fraser River in British Columbia (MacDonald, 1957). A flood-diversion channel is under construction to divert Red River flows around the city of Winnipeg (Dept. Res. and Dev., 1953). Several flood-control dams have been built in southern Ontario, such as the Fanshawe Dam on the North Branch of the Thames above London (Ont. Dept. Planning and Dev., 1952), and others are proposed such as the dams around Metropolitan Toronto (Metro. Toronto and Region Conserv. Authy., 1959).

In addition to these structures, watershed treatment has often been advocated as a means of reducing flood flows. While deforestation of watersheds may increase run-off rates and add to flood crests, it should not be assumed that reforestation and other watershed treatment will eliminate floods. These methods are playing a role in reducing flood hazards on some watersheds in southern Ontario, and in other parts of the country.

Frequently these and other methods of flood control are blocked by the very limitations inherent in the type of remedial action recommended. For example there is the real danger when recommendations are based primarily on benefit-cost analysis that the community will be given no more than one choice of action—either to carry out the recommendation or do nothing at all; no alternatives are offered.

### *The neglected choices*

*Flood proofing*—Flood proofing as one such choice has been examined by Sheaffer (1960). This is a form of flood-damage reduction that requires individual buildings to be made watertight by minor structural changes. Lower windows can be bricked up, steel bulkheads can be made to fit over door spaces and valves can be installed on drains and sewer outlets. For example in Winnipeg and Regina many buildings have sewer caps which can prevent back-up into basements. Sheaffer discussed such adjustments in some detail, and after a careful study concluded that flood proofing is a valuable alternative method of flood-damage reduction and suggested six kinds of situations in which flood proofing of buildings may be especially desirable. These are: (1) where low-stage, low-velocity, moderate flooding of short duration is experienced; (2) where the more traditional kinds of flood protection such as dams and dykes are not feasible; (3) where individuals desire to solve their flood problems without collective action or where collective action is not possible; (4) where cultural groups shun government aid and subsidy but wish to mitigate their flood losses; (5) where activities which demand riverine locations in order to function, need some degree of protection; and (6) where a resource manager desires a

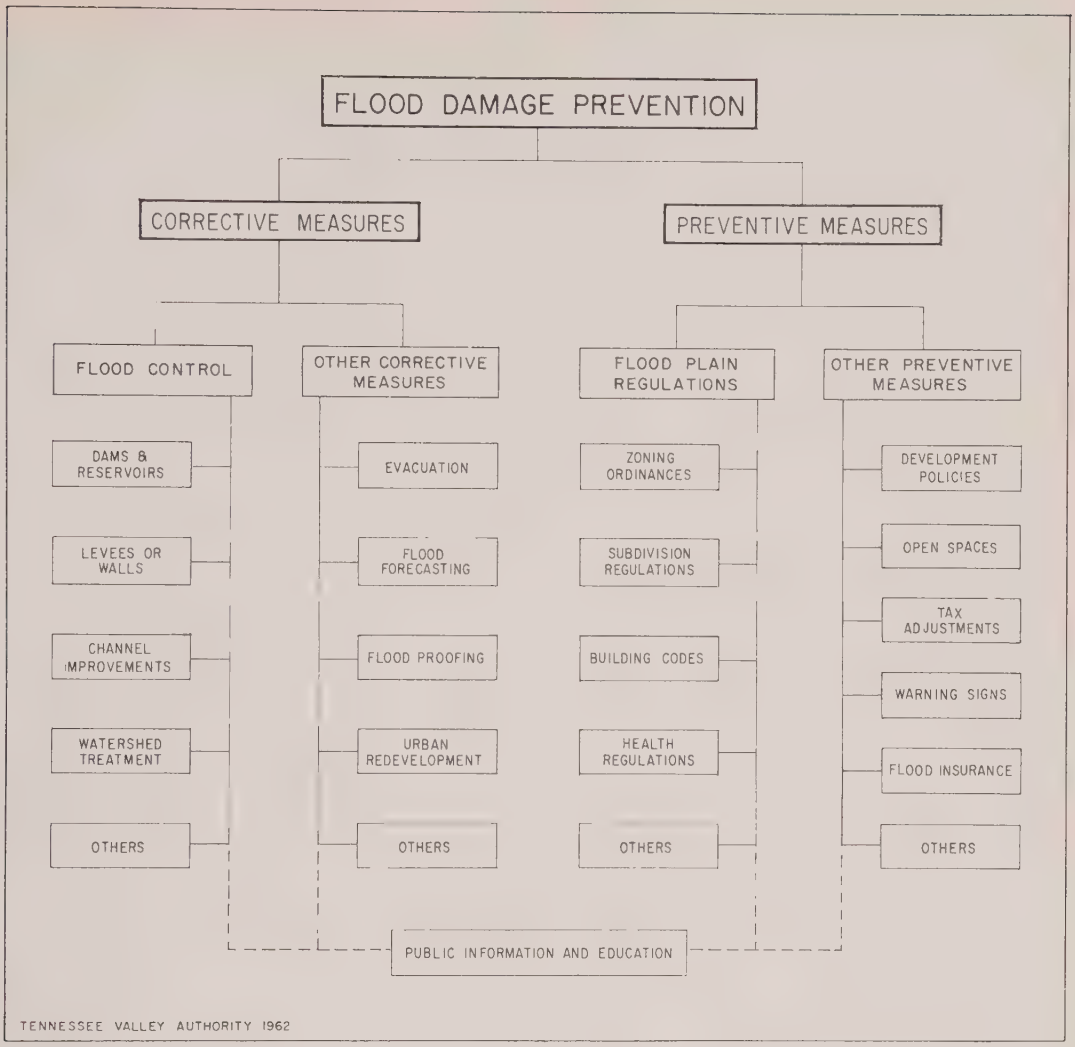


FIGURE 6. Alternative adjustments to flood.

higher degree of protection than that provided by a flood-control project.

Flood proofing is a flexible adjustment to flood hazard and can be used either by itself or in conjunction with flood-control projects, flood-plain regulations, or flood-damage insurance as in the Golden Triangle area of Pittsburgh (Sheaffer, 1960). It can also be undertaken privately or at government expense or under a cost-sharing arrangement.

*Urban redevelopment*—Many cities with flood problems have large sections of their central business districts on the flood plain. These urban cores and the surrounding zone of mixed housing and industry are commonly the oldest part of the city, and many of them are now or soon will be in need of renewal.

Accordingly a program aimed at eliminating flood damage in addition to removing damageable property leads directly to urban redevelopment. Such cities as Galt (Bell, 1963), and Belleville, Ontario, where the main street parallels the banks of a river and where the backs of main street properties stand directly on the bank of the river, are examples of a situation common in many smaller cities. Urban redevelopment in such situations could fulfill a triple function by (1) removing damageable property from the path of

floods, (2) creating more public open space along the waterfront and thus adding to the attractiveness of the business centre, and (3) providing more parking space and thus helping to revitalize the central business district.

*Flood-plain regulations*—Under this broad heading a number of social guides are possible that will channel development in the most desirable places and avoid undue creation of new flood-damage potential. Such guides include encroachment statutes, building codes, zoning ordinances and the like. It is not necessary to view this as negative legislation, the only purpose of which is to prohibit development. On the contrary, it can be used to ensure that flood plains are utilized to their maximum advantage, while reducing, in so far as is possible, the risks taken by private citizens.

*Flood insurance*—The private insurance business has not ventured into the field of flood-damage insurance (Am. Ins. Assoc., 1956). There are good reasons for this. Most property is not subject to flood and would, therefore, have no need for flood insurance; but property located on flood plains will be flooded sooner or later and the group of people involved would have to share the burden of a flood-damage insurance program. Basic data needed for determination of fair and equitable premiums for areas of varying flood risks are not yet available. Hence flood insurance is prohibitively expensive and for most practical purposes is not available. There remains the possibility of government-sponsored flood insurance. This would produce problems of accelerating movement into flood plains, unless premiums were realistically related to risks.

*Flood forecasting*—Flood forecasting is being widely used and modern communications make this method of flood-damage reduction potentially one of the most effective. How effective it is at the present time is difficult to assess. A fruitful study could be made of the amount of damages prevented by flood forecasting in relation to the cost of providing the forecasts. It seems likely that such a study would show very large benefits from flood forecasting in relation to costs.

Although flood forecasting is capable of further refinement and development it is not a neglected alternative in the sense of the other methods discussed above. One qualification is needed here. Flood forecasting by itself is less effective than when combined with public efforts to increase flood hazard awareness. If citizens located on the flood plain are made aware of the danger then they will be better prepared to take emergency steps to reduce damage. Such steps may include evacuation of people and valuable property from the hazard area, elevation of property beyond the reach of flood waters, emergency sandbagging and the like. Where flood hazard awareness is low, plans for dealing with an emergency may be relaxed or poorly developed and even the receipt of a timely flood warning may not allow effective measures to be taken. For example, sand and sandbags may not be readily available and transport for the removal of goods may not be quickly obtained.

A second point about flood forecasting is that great care needs to be exercised to make warnings accurate. A series of unfulfilled warnings can rapidly diminish the effectiveness of future warnings.

## EXTENDING THE RANGE OF CHOICE

The present study has presented evidence to show that if a wider range of choice can be offered with inducements to decision-makers in question of flood-plain land use and the reduction of flood damages, there is reasonable prospect that the periodic distress and suffering brought about by floods can be reduced substantially. In particular more vigorous steps are needed to prevent further undue growth of damage potential; to remove buildings from areas of high hazard; and to encourage flood proofing of those buildings that must remain in the path of floods. If these methods do not result in a substantial reduction in flood damages, at the very least they may be expected to restrain further growth. On the other hand if the range of choice to decision-makers is not extended, there is every prospect that flood damages will increase and that additional burdens will be thrown on governments in the form of the need to provide relief and rehabilitation for an increasing number of flood victims, and also to provide increasingly large-scale engineering works for flood control.

In order that the range of choice may be extended and that adequate guides to the choice can be made available, several innovations are required as well as extensions to present practice. There is need for more work on the hydrological aspects of floods. Studies of regional flood frequency and extent would be a useful starting point.

There is also need to recognize flood proofing of buildings as a legitimate method of reducing flood damages. If governments are prepared to spend large sums of money on engineering works for flood control, why not spend some small sums to assist flood-plain managers to flood-proof their buildings? A cost-sharing scheme would ensure that the money is well spent and is only used by those sufficiently concerned to make a contribution to their own protection. Another possible application of flood proofing is in those areas where the flood hazard is of a low order of frequency and the advantages of using the land for development are seen to outweigh the risks of infrequent flood damage. Here requirements for flood proofing could be added to the building code so as to ensure that, in the event of a flood, damages would be minimized.

Urban renewal and redevelopment legislation does not provide for use of funds to achieve other desirable and worthwhile objectives in addition to its main purpose. Where urban renewal projects are in prospect, steps could be taken to ensure that new uses of land conform to the national interest by minimizing the risk of future flood losses. There are also areas where the flood hazard itself could be the catalyst in starting an urban renewal scheme. This is particularly the case where engineering methods of flood control are found to be unfeasible.

A comprehensive program of flood-loss reduction would also include an increased emphasis on the flood-plain zoning work that is now taking effect in some cities. Local planning agencies are in need of assistance in drawing up suitable flood-plain regulations. For this purpose and for urban renewal schemes, it would be useful to have hydrometeorological studies of flood frequency, extent, depth and duration, in all the areas of the country where major flood damage potential exists. Such studies would aim at providing planners with a basis for rational choice of boundaries of hazard zones. For example, it may be possible to recognize parts of a flood plain as having distinctly different degrees of flood hazard. Regulations could be shaped accordingly to permit the maximum level of development consistent with the aim of minimizing flood damages.

Not all places with flood problems have established planning authorities to take action on flood-plain zoning, and even where planning authorities do exist there is frequently no readily available method of communicating information on flood hazard to private citizens. Often decisions to develop flood-plain land are taken by citizens who remain ignorant of the risks they are taking and to which they may be exposing others. There is need, therefore, for a flood-plain information program, both for the benefit of planners and for private citizens. In such a program flood-plain areas could be designated and shown on topographic maps, together with hydrological information on the nature and degree of hazard. Such a program could be made into a logical extension of the mapping work of an existing agency at an appropriate level of government.

It would be most helpful if the agency preparing information on flood hazards could also be made responsible for collecting flood-damage data. This leads to the suggestion that a central collection and depository office be established to gather together in one place information on flood hazard, flood damages, and changes in flood-damage potential. Such an office could probably be established in an existing agency of government at relatively little extra expense. It could certainly expect to pay for itself in flood losses prevented by the wise policies of adjustments to floods which it would encourage.

It would be unwise to rush headlong into the establishment of a government-sponsored flood insurance program. Some possible advantages of such a scheme, however, suggest that it may be worthy of special investigation by a government committee of enquiry. After careful thought it may be possible to devise a scheme in which flood insurance would play a useful role along with other methods of adjustment to floods.

In planning a flood policy for the next few years, there are advantages to be gained from a broader and more flexible approach than has yet been used. In particular flood-plain zoning, urban renewal for flood-damage reduction, and flood proofing merit more serious attention. These alternatives have been relatively neglected. Continued rapid population growth, and continued urban expansion can mean a much higher bill for flood losses and flood control works under existing policies and arrangements for flood-damage reduction.

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# DEPOPULATION OF FARMS IN RELATION TO THE ECONOMIC CONDITIONS OF AGRICULTURE ON THE CANADIAN PRAIRIES

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ABSTRACT

During the ten-year period preceding the last census, the farm population in the prairie provinces declined by almost 200,000. The spatial association between the degree of depopulation in the period from 1951 to 1961 and the economic conditions of agriculture as reflected in the 1961 census data is examined. Multiple regression analysis was applied through a series of statistical models to data pertaining to 56 areal units of observation. The four most relevant variables statistically explain 62 per cent of the spatial variation in the net migration from farms. These are: (1) proportion of small commercial farms; (2) proportion of small scale farms; (3) rented area per farm; and (4) paid labour per farm. Areas which achieved a relatively lower degree of farm population balance and from which migration is expected to be relatively more intensive in the future were delineated on the basis of mapping residuals from regression.

RÉSUMÉ

Au cours des dix années précédant le dernier recensement, la population agricole des provinces des Prairies a diminué d'environ 200,000 personnes. L'auteur étudie les relations spatiales entre les taux de dépopulation au cours de la période allant de 1951 à 1961 et la situation économique de l'agriculture telle qu'elle est reflétée par les données du recensement de 1961. L'analyse multiple des régressions a été menée à l'aide d'une série de modèles statistiques établis avec les données relatives à 56 unités régionales d'observation. Les quatre variables les plus pertinentes expliquent statistiquement 63 p. 100 de la variation spatiale dans l'émigration nette à partir des fermes. Ce sont les suivantes: (1) pourcentage des petites fermes commerciales; (2) pourcentage des fermes de faible étendue; (3) superficie louée par chaque fermier; (4) main-d'œuvre payée par chaque fermier. Les régions dont la population agricole ne jouit que d'un équilibre économique assez médiocre et d'où l'émigration semble devoir se produire de façon plus intense dans l'avenir ont été délimitées par la cartographie des résidus statistiques de régression.

## INTRODUCTION

### *Statement of the problem*

The decline of rural population represents a complicated process of adjustment between population distribution and economic opportunities.

Migration from farms can be considered an ever-present problem because agricultural areas almost always produce surplus populations the farming industry cannot absorb. The surplus is usually the product of a significantly higher birth rate and a moderately lower death rate among farm people than among the urban population, and this factor alone probably contributed to some extent in the past to the maintenance of a population imbalance on the Canadian prairies. The instability of population, however, was also greatly aggravated by specific economic-historical developments.

Most parts of the Canadian prairies were settled for the first time within living memory. Homesteaders were distributed on lands apportioned on the basis of surveyed quarter sections irrespective of physical conditions for agriculture (Sask. Roy. Com. on Agr., 1956, pp. 39–82). There was little information available on such factors as climate and suitability of land. The

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haste with which settlement was carried out did not allow time for such considerations. The population density which emerged originally in this way had, therefore, little or no bearing upon the productivity of soil, and areas with limited productivity became overpopulated during the settlement period. Thus the pattern of rural population distribution contained a strong element of imbalance as it came into being and was bound to be disrupted even without the impact of greater technological changes in later years.

Technological change during the last few decades has brought a transition to a thoroughly mechanized, commercialized, urbanized and scientific agriculture. The single most important effect of the change has been a spectacular increase in agricultural productivity in the Canadian prairies unequalled anywhere except in the American mid-western and plains-states. Agriculture has changed from a labour-intensive to a capital-intensive industry. The increased capital requirement of agriculture at the enterprise level will produce higher incomes provided the scale of production makes possible the economic utilization of equipment and other production facilities. Farms that are too small to be operated as economic units find it impossible to raise the necessary capital for increasing their productivity and their income; their owners turn to other industries for their livelihood.

People migrate from farms when "pushing" factors such as unfavourable economic conditions on the farm and "pulling" factors such as favourable economic conditions elsewhere prove to be persuasive enough in the personal judgment of the individual to induce a decision for relocation. A change of farm residence for a non-farm residence, however, may or may not involve the abandonment of farming as an industry. Family members who never were farmers themselves may move to other places, or farmers moving to urban residences may continue farming as a means of living. There are signs indicating that the movement from farms associated with the decrease in number of farm operators and the increase in size of farms may slow down in the coming years. On the other hand, the movement to urban residences of farm people who continue farming may go on or even accelerate, resulting in an increase of non-resident farm operators.

The adjustment of population distribution to economic opportunities cannot be administratively regulated at will in a free society. By thorough examination of recent developments, however, future adjustments may be anticipated and the eventual adverse effects of them counterbalanced by appropriate measures. It is assumed, therefore, that examination of these problems may be useful; the magnitude of the problem also warrants such examination.

In 1951 there were 904,000 people living on farms in those areas of the prairies proposed for examination. The 1961 census found 722,000 people living on farms in the same areas. Had there been no migration from the farms, the 1961 census should have found an estimated 1,087,000 people. The difference of 365,000 between the "expected" and actual farm population, or 33.6 per cent of the 1961 expected farm population, represents the net migration from the farms as a result of a two-way movement.

The percentages of negative net migration of farm people for the individual prairie provinces are remarkably close to the over-all prairie average: 32.7 (Manitoba), 34.9 (Saskatchewan) and 32.5 (Alberta). The degrees of depopulation computed for each of the major soil zones show somewhat greater variations: 27.8 per cent (Brown soil zone), 31.9 per cent (Dark Brown soil zone), 31.4 per cent (Black soil zone), 40.3 per cent (Grey Wooded and transitory soil zones). Examining data for census divisions, it was found that at least 18.3 per cent and at most 60 per cent of the 1961 expected farm population was missing at the time of the 1961 census.

Apparently, the economic conditions existing on the farms exerted a considerable influence on the process of migration away from the farms. It is the purpose of this paper to examine the association between the degree of farm depopulation in the period from 1951 to 1961 and the economic conditions of agriculture existing on the Canadian prairies as reflected in the 1961 census data. It would perhaps be more appropriate to examine farm population *changes* in light of the *changes* in economic conditions during the intercensal years. Practical considerations, however, ruled this out. Boundaries of census divisions, which are the areal units of observation in this study, have been revised so extensively for both Manitoba and Alberta that comparable economic data were not available. Farm population figures for 1951, however, were retabulated for the revised subprovincial areal units for these two provinces and published in the 1961 census volumes.

*Scope, methodology*

The area within the scope of this study is the southern settled parts of the prairie provinces (Figure 1). The most notable exclusion is the Peace River region of Alberta where socio-economic conditions of settlement and farming are unique in many respects. Indian reserves, national and provincial parks, and certain fringe areas where agriculture is only incidental as an industry were also deleted from the study.

In order to introduce a measure of precision into the statements on the hypothesized relationship between depopulation of farms and economic conditions on the farms as described by a number of variables, multiple regression analysis was applied through a series of statistical models. The computations were done on the IBM 705 III computer of the Dominion Bureau of Statistics using stepwise regression program REGRO I (phase I for simple correlation analysis) and REGRO 3 (phase II for the multiple regression analysis in a stepwise fashion). The program has been developed by J. J. Foster of the Scientific Section, Central Programming staff, Dominion Bureau of Statistics from earlier work by K. W. Smillie.

*Organization of computer input*

A cursory inspection of data indicated a strong relevance of the major soil zones running across the prairie provinces to the farm population and farm economic indices. The following chi square test illustrates this relevance:

*Chi square test*

$$\chi^2 = \Sigma \frac{(f_o - f_t)^2}{f_t}$$

| Soil zones | Apparent no. of migrants from farms (000's) | | | |
|---|---|---|---|---|
| | Observed* $f_o$ | Expected** $f_t$ | $(f_o - f_t)$ | $\frac{(f_o - f_t)^2}{f_t}$ |
| (1) Brown | 37.4 | 48.7 | −11.3 | 2.6 |
| (2) Dark Brown | 59.2 | 64.4 | − 5.2 | 0.4 |
| (3) Black | 144.6 | 158.8 | −14.2 | 1.3 |
| (4) Grey Wooded | 123.9 | 93.2 | +30.7 | 10.1 |
| | 365.1 | 365.1 | $\chi^2$ = | 14.4 |

*Difference between (1) actual census population on farms in 1961 and (2) 1951 farm population plus the computed number of natural increase.

**Expected number of migrants in each soil zone if their distribution among the soil zones were the same as that of the actual farm population at the 1961 census.

This $\chi^2$ value of 14.4 with 3 degrees of freedom yields a probability value of less than 1 per cent.

The null hypothesis that there was no significant difference between the distribution of migrants and that of the farm population among the four major soil zones was tested above. The obtained $\chi^2$ value of 14.4 means that this null hypothesis would produce differences as large as this only by chance-occurrence less than one time in a hundred. There is, therefore, more than 99 per cent probability that the frequency with which migrants were distributed among the soil zones was not a pure reflection of the distribution of the farm population itself. Therefore it is reasonable to expect that these soil zones possess characteristics and attributes which influence the number of migrants from farms.

In order to preserve the reflection of this influence in the data it was deemed desirable to have areal units of observation whose boundaries would not cross those of any major soil zone or zones. In other words it was required that each areal unit of observation be located entirely in any one of these soil zones so that the technique of analysis would not lessen or cancel out influences attributable to differences in conditions prevailing in each of the major soil zones.

Fortunately, census divisions which were chosen as units of observation were revised for Manitoba and Alberta before 1961 in such a way that they fully satisfy the above requirement. Census divisions in Saskatchewan in 1961, however, did not, and the delineation of a set of subprovincial areal units suitable for areal analysis was necessary. For the sole purpose of this study 26 such areal units (designated here as "areal divisions") were devised. Only two requirements were observed in delineating these units: (1) each areal division had to be located in any one of the four major soil zones; and (2) within any one areal division farm population density had to be largely uniform. A third but not strict requirement was that, if possible, areal divisions be largely comparable in size, to help facilitate the application of statistical technique. Appendix I illustrates the Saskatchewan census divisions existing in 1961 and the areal divisions devised for this study.

Farm population and other data were retabulated for these new divisions in Saskatchewan and the necessary deletions made from the data for Manitoba and Alberta. For this purpose, census of agriculture data were needed at the municipal-



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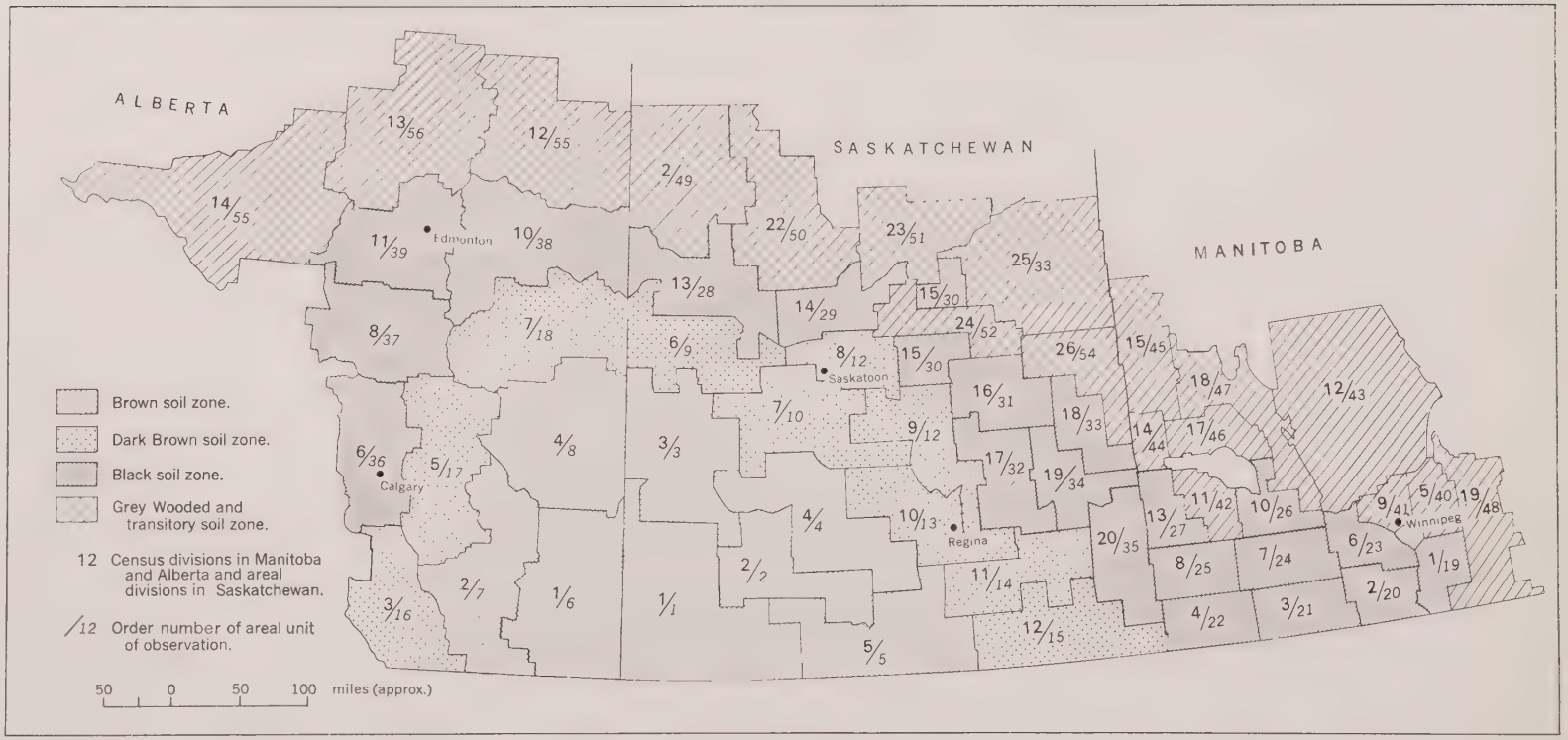


FIGURE 1. Location map.

ity level. Some were available from published sources but the bulk of them was obtained through the courtesy of the Dominion Bureau of Statistics in the form of photostatic copies of computer outputs. Data were then transferred to punch-cards and retabulated in the desired way by mechanical or electronic means.

The definition of "farm" as used in the 1961 census differed from the definition used in 1951. The necessary adjustments to data for definitional change were done at the census division level in Manitoba and Alberta and areal division level in Saskatchewan.

Computing estimates of depopulation of the farms for the period of 1951–1961 posed a problem. The difference between the 1951 actual farm population and the farm population which could be "expected" in 1961 had there been no migration was considered as apparent net migration. These latter expected figures were obtained by adding estimates of births to and deducting estimates of deaths from the 1951 data. Since there is no significant difference between mortality levels for rural (excluding Indians) and for total population in recent years, death rates for total population and for each province were applied. In producing estimates of births it was considered necessary to make allowance for differentials in this respect between the rural and urban scenes. The ratios between children under 5 (C) and total population (T) for farm population (subscript f) and for general population (subscript g) respectively were used as correction factors to adjust the birth rates for the general population ($B_g$) and obtain estimates of birth rates for the farm population ($b_f$):

$$b_f = B_g \frac{\frac{C_f}{T_f}}{\frac{C_g}{T_g}}$$

The above procedure was verified by data obtained from hospital statistics. The number of births in hospitals to mothers with a rural residence was compared to all hospital births after excluding Indian births and adjusting figures of births and covered population* to 100 per cent. Allowance was also made for the fact that these data covered all rural areas and not only rural farm areas. The results were remarkably close to those obtained through the technique described above.

All these estimates were done separately for each province.

The number of areal units as subjects of observation is 56. They are not uniform in size; in order to provide a measure of formal allowance for these differentials, the data prepared for analysis were weighted. The weighting system used is based on the indirect standardization technique as it is known in demography (Duncan, Cuzzort and Duncan, 1961, pp. 34–38). The actual number of farm population in each areal unit at the 1961 census was used as weight.

Despite this an informal allowance was also given for size differentials and a conservative attitude was taken in the course of interpreting the results.

## THE HYPOTHESES

Depopulation of farms was measured by ratios obtained by relating the number of apparent migrants to the expected population on farms in 1961. The sums of the 1951 farm population and the computed natural increase gave the expected population. These "ratios of depopulation" ($X_1$) were used as the dependent or criterion variable.

Fifteen indicators each relevant to the economic conditions on the farms at the time of the 1961 census were selected and retained in the analysis as being in logical relationship with the movement of farm people. These were the independent or predictor variables. The hypotheses that these relationships areally exist were tested by computing simple correlation coefficients (r) between the dependent and each of the independent variables on the basis of 56 observations and tested for statistical significance at the 99 per cent level. Simple correlation coefficients were also computed between each variable and all the other variables for eventual cross-reference purposes. A list of variables is found in Appendix II.

A review of these hypotheses and the results of the computations are as follows:

Variable $X_3$ denotes rented farm area per farm. It was hypothesized that in areas where the proportion of rented farm land is large, the farm population is more stable and there is a reduced number of outmigrants now since outmigration from farms of earlier times was a major cause of the increase in rented farm areas of present times.

*Those under the provisions of the respective provincial hospital insurance programs.



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Where overpopulation of the countryside relative to resources and economic conditions became obvious and untenable historically earlier, people moved out of farms and made land available for rent for those who remained. Another consideration was that in areas settled at a later stage of development, farm lands for rent are not yet available to a large extent. At the same time, in many of these areas the pressure became heavy on the farm population and many were inclined to leave. The correlation of −0.408 between rented farm area per farm and outmigration from farms is consistent with this hypothesis.

There are relatively high correlations expectedly between this variable ($X_3$) and a number of other variables included in the study: farm land cropped per farm ($X_5$), 0.639; paid labour ($X_{11}$), 0.466; value of products sold per farm ($X_{17}$), 0.565, etc. Surprisingly, the correlation of rented farm area per farm ($X_3$) with return per unit of capital (total value of products sold per total capital value of farm) $X_{18}$, is a low 0.175 which is below the statistically required significance level (5 per cent). This indicates that although rented areas make farm operations larger* in terms of land and capital turnover, they do not always contribute significantly to the financial success of farming.

Variable $X_4$ represents farm land improved per farm. The well established notion that, the larger the average size of farms in an area (in this case in terms of improved farm land) the less migrants originate from farms, is incorporated in this variable. The correlation between depopulation and this predictor is −0.452. Although it is well over the significance level, it is still somewhat less than would be expected, indicating that size of operation in physical terms has no overwhelming effect on migration at this time. Correlations of this variable with some of the others show some interesting relationships: there is a strong negative correlation, as expected, with part-time farm operators ($X_8$), −0.490; a strongly positive one with rented area ($X_3$), 0.648. An even higher correlation results if farm rental is examined in financial terms: with rent paid ($X_{13}$) the coefficient is 0.879. That the size of farm operation described in financial terms is more successful in exploring relationships in the present context is further indicated by this fact: variable $X_4$ (farm land improved) with variable $X_{15}$ (value of machinery) gives a correlation of a very high 0.966; with variable $X_{17}$ (value of products sold) a lower 0.796; and with $X_{18}$ (return per unit of capital) an even lower 0.489. The values of the correlation coefficients decreased as the latter two variables relevant to the financial outcome of operation were introduced.

Another variable, also indicating the size of farm operations is $X_5$, farm land cropped. Depopulation of farms ($X_1$) shows a higher correlation with this variable; −0.471, than with the previous one ($X_4$, farm land improved). This is an indication of the fact that higher proportions of the improved lands are cropped where migration from farms is also higher. The relationship of this variable with certain typical variables shows the same pattern as $X_4$ above.

The proportion of part-time farm operators to all farm operators (variable $X_8$) was also considered hypothetically as being associated areally with depopulation of the farms. Part-time farm operators were considered as candidates for outmigration in many cases. Where conditions on the farms created a relatively high number of part-time operators who gave up farming as a sole means of living, thereby being to some extent outside of the farming industry, it is likely that the same conditions also induced a relatively high number of people to leave the farms. The validity of this hypothesis is supported by a correlation coefficient of 0.409 between these two variables. As expected, there is a significant inverse relationship between part-time farm operators ($X_8$) and such indices as farm land cropped ($X_5$), −0.475; paid labour ($X_{11}$), −0.312; and taxes paid ($X_{12}$), −0.479.

Paid labour was measured by the number of male labour weeks per farm ($X_{11}$) and hypothesized as being inversely related to depopulation. Relatively high values of this variable would indicate relatively large farm operations and in these areas outmigration from farms is expected to be moderate. The dependent variable ($X_1$) has a correlation of −0.535 with this variable. Among the correlations which paid labour ($X_{11}$) has with the other variables, two merit attention: with $X_5$ (cropped land) the coefficient is a moderate 0.431; and with $X_{14}$ (total capital value) it is a very high 0.852. This is a further indication that indices expressing the size of farm operations

*In the majority of cases rented farm lands are additions to owned holdings and serve the purpose to enlarge the farming operations. (One-third of all farm operators were part owners and part tenants, and less than one-tenth owned no land but rented the entire holding.)

in financial terms are more relevant in this analysis than those expressing farm size in physical terms.

Variable $X_{12}$ denotes taxes paid. The correlation of this variable with depopulation, although well over significance level, is a surprisingly low −0.401. Conceivably this is only a reflection of the fact that taxation is not so closely linked with income situations and consequently with depopulation as expected. Coefficients of correlation that variable $X_{12}$ has with three others support this suggestion: part-time farms ($X_8$), −0.479; paid labour ($X_{11}$), 0.378; and especially return per unit of capital ($X_{17}$), 0.494. If taxation was closely associated with income situations all these coefficients would be considerably higher.

Variable $X_{13}$ denoting rent paid was included on the basis of the same considerations as $X_3$ (rented area): this variable was expected to be inversely associated areally with depopulation. The two variables, however, have different attributes as the correlation analysis revealed: the correlation coefficient between depopulation and rent paid is a significant but very low −0.252. This is considerably lower than between depopulation and rented area ($X_3$) which is −0.408. The reason is the fairly loose correlation between rent paid and rented area: 0.384.* On the other hand, rent paid ($X_{13}$) has a significantly higher positive correlation with return per unit of capital ($X_{18}$), 0.484, than has rented area ($X_3$) which is an insignificant 0.175 as seen above. Rent paid also has a higher correlation with value of products sold ($X_{17}$), 0.677 than has rented area 0.524.

Total capital value of farms, variable $X_{14}$, was deemed to be highly associated with farm population movement. Areas where the capital value of farms is high would obviously send fewer people on their way. This reasoning is valid; the correlation between depopulation and this variable is a respectable −0.562, which is the highest coefficient exhibited by any independent variable so far introduced. Perhaps even a higher value could be expected. The reason it is not so is that in areas where depopulation is relatively high and farms are small, the proportion of unproductive** capital is larger than in areas where the opposite holds. Furthermore, the productive† portion of capital is overvalued in terms of its capability of generating income, as will be seen later. At this point it is sufficient to note that while the correlation of total capital value of farms with value of product sold ($X_{17}$) is an expectedly very high 0.929, on the other hand high level of capital investment does not always result in high values of return per unit of capital. The correlation between total capital value and return per unit of capital ($X_{18}$) is a significant but low 0.375.

One of the most important components of farm capital investment, the value of farm machinery and equipment was also selected as a variable ($X_{15}$). It was hypothesized that high level of investment achieved in machinery and equipment is indicative of good conditions for agriculture and should, therefore, be inversely related to migration from farms as a means of economic adjustment.‡ This hypothesis is valid; the correlation between these two variables being a fairly high −0.524. The same question, as in the case of total capital value, may arise: why is this correlation not even closer? One reason may be that in poorer areas whence outmigration is relatively large, machinery and equipment are overvalued in terms of their income-producing capability under the given circumstances. Furthermore, there may well be a measure of genuine excess value of machinery which cannot be economically utilized because of the smallness of the holdings in these areas, or for other reasons. Raw data seem to support these arguments:

*Value of machinery and equipment per acre of cropped land*

| | |
|---|---|
| Prairie provinces | $31.9 |
| Brown soil zone | 28.5 |
| Dark Brown soil zone | 28.5 |
| Black soil zone | 34.3 |
| Grey Wooded soil zone | 36.6 |

Value of machinery per unit cropped land was the highest where depopulation was also highest.

*Understandably land rents vary with the quality of land, with the actual success of farming at particular times and places and with other factors; e.g. in 1961 the actual rents paid in cash or kind for each acre of rented land was: Brown soil zone $1.00, Dark Brown soil zone $1.60, Black soil zone $2.00 and Grey Wooded soil zone $1.10.

**Farm homes. (In some instances the "real estate" values were reported by enumerators instead of the "market value".)

†Land, machinery, livestock.

‡In a time series analysis another hypothesis could be formed: high *rate* of investment in machinery would be expected to be directly related to high *rate* of outmigration.

Obviously the best use was not made of the high ratio in such areas, as the following raw data shows:

*Value of products sold per dollar invested in machinery and equipment*

| | |
|---|---|
| Prairie provinces | $0.74 |
| Brown soil zone | 0.83 |
| Dark Brown soil zone | 0.81 |
| Black soil zone | 0.71 |
| Grey Wooded soil zone | 0.54 |

Depopulation varied inversely with the above values. Data deriving from the correlation analysis also support these arguments. While value of machinery and equipment ($X_{15}$) correlates closely with value of product sold ($X_{17}$) ,0.898, indicating relatively large turnovers in production going with it, it does not correlate with return per unit of capital ($X_{18}$) to the same extent, 0.522, pointing to a reduced ability of investment in machinery to generate income under disadvantageous circumstances.

Value of products sold, variable $X_{17}$, is relevant to the size of the farm operation in financial terms and should be inversely associated areally with depopulation. The correlation between these two variables is a relatively high −0.565. Among correlations $X_{17}$ has with other variables, although none of them is unexpected, only one merits notice: with return per unit of capital ($X_{18}$) the correlation is a relatively low 0.673. This is also understandable from the argument submitted above.

Return per unit of capital ($X_{18}$) was included in the analysis because areas with low returns on capital, thus exhibiting economic stress, were expected to have a large number of migrants from farms in response to the pressure. A much lower correlation than expected resulted: −0.392. Two suggestions may be submitted to explain this moderately close association: (1) even in areas where the *ratio* of return per unit of capital is high the sheer *volume* of it may not provide sufficient incomes, and people leave; or the opposite, where the ratio is low the volume may be quite adequate and people stay; (2) the social inertia of people who more or less accept rural poverty as a way of life, who theoretically should move but will not or cannot, also depress the value of this correlation coefficient.

Variable $X_{19}$, denoting commercial farms was also considered as inversely associated with depopulation. The correlation between the two is −0.322; although significant statistically, it is very low. A higher correlation could hardly be expected since commercial farms include small and otherwise disadvantageous holdings as well as large and prosperous ones.

The separation of this category was carried out by introducing the extreme ends of the distribution as two independent variables: large commercial farms ($X_{20}$) and small commercial farms ($X_{21}$). These variables have considerably higher correlation with depopulation than has $X_{19}$: with $X_{20}$ a high negative value of −0.635 and with $X_{21}$ a high positive coefficient of 0.648. This latter, small commercial farms, shows the highest correlation with depopulation among all the independent variables analyzed.

It is significant that small commercial farms ($X_{21}$) has an even closer positive correlation with depopulation than small scale farms ($X_{22}$) which is 0.647. This is so despite the fact that small commercial farms are better off than small scale farms with respect to three important variables: total capital value, total value of products sold and return per unit of capital. Small commercial farms ($X_{21}$) has a negative correlation with these three variables respectively: −0.589, also −0.589, and −0.365, as against those of small scale farms: −0.719, −0.717 and −0.529. It is reasonable to suppose, then, that in some cases the economic stress on small commercial farm operators may be even higher than on small scale farm operators among whom a larger proportion may have an alternate source of income that relieves some pressure. Approximately one-third of the small scale farmers are working on their holdings part-time, and many may carry on with a relatively small farm income supplemented with revenues from other established sources.

A review of all the independent variables, whose relationships with depopulation were explored separately, is as follows:

*Simple correlations* between depopulation of farms and the independent variables*

| | |
|---|---|
| $X_1$ with $X_{21}$ = 0.648 | $X_1$ with $X_4$ = −0.452 |
| $X_1$ with $X_{22}$ = 0.647 | $X_1$ with $X_8$ = 0.409 |
| $X_1$ with $X_{20}$ = −0.635 | $X_1$ with $X_3$ = −0.408 |
| $X_1$ with $X_{17}$ = −0.565 | $X_1$ with $X_{12}$ = −0.401 |
| $X_1$ with $X_{14}$ = −0.562 | $X_1$ with $X_{18}$ = −0.392 |
| $X_1$ with $X_{15}$ = −0.524 | $X_1$ with $X_{19}$ = −0.322 |
| $X_1$ with $X_{11}$ = −0.535 | $X_1$ with $X_{13}$ = −0.252 |
| $X_1$ with $X_5$ = −0.471 | |

*Significant at the 99 per cent level.

Correlation coefficients are listed in order of their magnitude irrespective of their signs. This rank order is valid only if relationships of each predictor with the dependent variable is examined separately.

However useful these coefficients are in the analysis their value is limited in two respects: (1) they give no information on the degree to which three or more variables are associated; and (2) they provide only summary statements relating to the whole area of study, leaving the areal variations of these average relationships unexplored.

In order to fill this void, multiple regression analysis was applied.

## THE ANALYSIS

The 15 independent variables were grouped using their intrinsic differences as criteria. These groups were then used as prediction models to examine the association between depopulation and a set of independent variables included in each model.

For each model, linear regression equations were computed:

$$Y_c = a + b_1 X_1 \ldots b_n X_n$$

along with values of coefficient of multiple determination ($R^2$) and coefficient of multiple correlation (R). Values of components added to $R^2$ at each step were also computed.

On the basis of each model the magnitude of the dependent variable (depopulation or "negative population growth" as it is defined in the regression analysis) was computed ($Y_c$) for each of the 56 areal units of observation. These values of $Y_c$ indicate the magnitude of the dependent variable that would exist if the variation of depopulation corresponded perfectly in a linear way with the variation of the predictor variables included in that particular model. In fact, they never correspond perfectly and the amounts of departure, i.e., the observed values (Y) from the computed values ($Y_c$), or the residuals from regression

$$Y - Y_c$$

provide a good means to express areal variation in the magnitude of prediction each model can offer (Thomas, 1960).

Four models were designed; the fifth model includes all the independent variables. Regression residuals were obtained for each model in $Y - Y_c$ form, and their mapping was facilitated by the graphs on which these values were plotted by the computer. These residuals are in the same terms as the dependent variable. In the case of Model V residuals were expressed and mapped in "relative" terms as well:

$$\frac{Y - Y_c}{Y} \times 100$$

which depict the percentage proportions of the dependent variable explained by the regression line for n-th unit area. For Model V residuals were computed and cartographically presented in terms of the standard error of estimate ($S_{y_c}$) for the 56 observations:

$$\frac{Y - Y_c}{S_{y_c}}$$

In a particular areal unit and in terms of the regression residual $Y - Y_c$ depopulation of farms is overpredicted if the value of residual from regression is negative and underpredicted if this value is positive.

A discussion of each model and map follows.

*Model I*

The first model comprises those independent variables that are relevant to the size of farm operations in an area and that separately exhibit statistically significant relationships with depopulation.

*Multiple regression equation, Model I*

$$X_1 = -36.060 + \underset{(0.0170)\dagger}{0.0240\ X_5} - \underset{(0.287)\dagger}{0.526\ X_8} + \underset{(0.006)\dagger}{0.008\ X_3}$$

$$R = 0.536^* \quad R^2 = 0.287$$

Components added to $R^2$ at each step:

| | |
|---|---|
| $0.222\ X_5$ | farm land cropped |
| $0.044\ X_8$ | part-time farm operators |
| $0.021\ X_3$ | rented area |
| 0.287 | |

*Significant at the 99 per cent level.

†Figures in brackets represent the standard errors of the regression coefficients.

The equation above reveals that among the variables included in this model, farm land cropped ($X_5$) is the most successful indicator in explaining areal variations in depopulation.

Part-time farm operators ($X_8$), and rented area ($X_3$) follow in diminishing order. The value of the coefficient of multiple determination ($R^2 = 0.287$) is relatively low, though significant.

Figure 3, depicting the residuals from regression in terms of the dependent variable for Model I indicates almost all of Manitoba and large areas of the mid-section of Alberta as overpredicted. The semiarid southwest of Saskatchewan and the area around North Battleford are also overpredicted along with Areal Division (A.D.) 9 in the middle of the province. On the other hand, areas on the northern fringe of Alberta and Saskatchewan are shown to be heavily underpredicted, and certain southern and mid-section moderately underpredicted areas are mixed with slightly underpredicted ones. In Manitoba only Census Divisions (C.D.) 11 and 17 and the portion of 19 that is included in this study are underpredicted, none of them heavily.

The general pattern of the distribution of residuals on this map indicates to some extent the degree of balance the farm population achieved so far. Where outmigration from farms began historically earlier, such as southern Manitoba, or where relative overpopulation resulted in an untenable situation in earlier periods, such as in the semiarid areas of Saskatchewan and Alberta, a better balance was achieved before 1951 and outmigration was only relatively moderate after that; thus these areas generally are overpredicted in this Model. On the other hand, in areas that were settled historically later, such as some of the northern fringe areas of Saskatchewan and Alberta, or where survival conditions on farms during times of economic stress were easier (for example, parkland areas of Saskatchewan and Manitoba) outmigration was slower before 1951, or even some earlier migrants returned; all these areas necessarily experienced a heavier outmigration during the study period and understandably are underpredicted in in the Model.

The general pattern of distribution of residuals deriving from Model I (Figure 3) reveals a close relationship with the distribution of the dependent variable itself as shown by Figure 2. Values of coefficient of variation ($\sigma_Y$; where Y is depopulation and $\sigma$ is the standard deviation thereof) are high where depopulation was low and low where depopulation was high. Areas with low values of coefficient of variation, by and large, coincide with areas underpredicted on the basis of variables included in this Model. The opposite is true of areas showing high values of coefficient of variation. There are, however, notable exemptions such as the northern portions of Manitoba, in the middle portions of Saskatchewan and most remarkably C.D.'s 8 and 13 in Alberta where the ability of this Model to explain depopulation is the least.

*Model II*

Three variables are included in this Model, each of them relevant to farm operational expenditure:

*Multiple regression equation, Model II*

$$X_1 = -53.727 + 1.184\ X_{11} + 0.049\ X_{12} - 0.008\ X_{13}$$
$$\qquad\qquad (0.326)\dagger \quad (0.022)\dagger \quad (0.005)\dagger$$
$$R = 0.599^* \quad R^2 = 0.358$$

Components added to $R^2$ at each step:

| | |
|---|---|
| $0.286\ X_{11}$ | paid labour |
| $0.046\ X_{12}$ | taxes paid |
| $0.026\ X_{13}$ | rent paid |
| 0.358 | |

*Significant at the 99 per cent level.
†Figures in brackets represent the standard errors of the regression coefficients.

The coefficient of multiple determination ($R^2 = 0.358$) is somewhat higher for this Model than for the previous one. The above equation also indicates that paid labour ($X_{11}$) is the most important indicator in this Model and rent paid ($X_{13}$) the least important one in their contributions to the value of $R^2$.

A comparison of Figure 3 with Figure 4 illustrating the areal distribution of residuals from regression for Model I and Model II respectively, shows no profound differences in pattern. There are some minor differences throughout the study area in degree of over- or underprediction; but regarding a few areas there are significant differences as well. Census Division 4 of Alberta and Areal Division 10 of Saskatchewan are both slightly overpredicted on the basis of Model I and significantly underpredicted in terms of Model II. The opposite is true for C.D. 5 of Alberta and C.D. 5 of Manitoba which were significantly underpredicted areas and became slightly overpredicted as indicators of farm expenditures were applied in the regression against variables relevant to size of operation. This is a reflection of the fact that under the actual

conditions of an individual area, the explaining capacity of a model can vary to a considerable extent. Moreover, extreme cases in respect of certain variables and certain areas might be revealed that at times may also be useful, e.g., extreme actual values (means $\pm$ multiples of the standard deviation) of paid labour and/or rent paid are occurring in all of these areas identified above. At the same time, in Alberta C.D. 4 and Saskatchewan A.D. 10, Model II is in better concordance with the distribution of the actual depopulation than Model I.

*Model III*

In this model, such variables as total capital value ($X_{14}$), value of machinery ($X_{15}$) and value of products sold ($X_{17}$) were grouped together as being indicative of the size of farm operations in financial terms. The variable return per unit of capital ($X_{18}$) which is indicative rather of the financial outcome of the operation in terms of the total capital investment, was also included in Model III.

The following equation expresses the relationship between depopulation and this group of variables:

*Multiple regression equation, Model III*

$$X_1 = -106.261 \underset{(3.617)\dagger}{-6.854\, X_{17}} + \underset{(1.605)\dagger}{3.858\, X_{18}} + \underset{(0.585)\dagger}{1.487\, X_{14}} \underset{(1.236)\dagger}{-0.241\, X_{15}}$$

$$R^* = 0.631 \quad R^2 = 0.398$$

Components added to $R^2$ at each step:

| | |
|---|---|
| 0.319 | $X_{17}$ value of products sold |
| 0.068 | $X_{18}$ return per unit of capital |
| 0.010 | $X_{14}$ total capital value |
| 0.001 | $X_{15}$ value of machinery |
| 0.398 | |

*Significant at the 99 per cent level.

†Figures in brackets represent the standard errors of the regression coefficients.

The predicting power of Model III shows a further improvement over those of the preceding models; the value of the coefficient of multiple determination ($R^2$) being 0.398. The variable value of products sold ($X_{17}$) is the most powerful in establishing the statistical relationship expressed in this model, followed by return per unit of capital ($X_{18}$), total capital value ($X_{14}$) and value of machinery ($X_{15}$) in that order. The small contribution of this last variable to $R^2$ is noteworthy but not surprising keeping in mind that machinery and equipment for small farms is relatively overvalued in the census. On the other hand, return per unit of capital ($X_{18}$) shows closer bearing upon depopulation in the context of this model than might be expected when its relationship with depopulation is examined separately.

The spatial distribution of residuals from regression (Figure 5) of this model shows closer resemblance to that of Model II than to Model I. This is to be expected on the basis of the intrinsic relationship between variables incorporated in Model I on one hand and in Model II on the other. Naturally, size of operation in financial terms (expressed roughly by Model III) should be related more closely to operational expenditures (Model II) than to size of operation in more or less physical terms (Model I).

Model III is generally more effective in explaining depopulation, as the value of $R^2$ (0.398) indicates, than either of the preceding models. Apparently, this is not sufficient to result in a strikingly different spatial distribution of residuals of this model from those of the previous models. Nor can it be seen that the spatial pattern of residuals of this model exhibits a much closer approximation of the spatial pattern of the dependent variable itself than the previous models. This is apparent from the comparison of Figure 5 with Figure 2.

*Model IV*

Two independent variables relevant to the economic classification of farms are included in this model: small commercial farms ($X_{21}$) and small scale farms ($X_{22}$). It is well known that the basis for economic classification of farms is the value of products sold. Each class belongs to a certain "gross income" bracket. To some extent, however, they can be considered as composite variables as well, in the sense that each of them probably possesses attributes other than gross income and more prevailing within a class than in any other class. These common attributes of each class are not further explored in this study.

The multiple regression equation for Model IV reveals that this model is the most effective in explaining depopulation among the models so far presented, the value of $R^2$ being 0.577. Small commercial farms ($X_{21}$) is more significant than

small scale farms ($X_{22}$) in explaining depopulation. This confirms the findings of the simple correlation analysis where $X_{21}$ also varies somewhat more closely with depopulation than does $X_{22}$.

*Multiple regression equation, Model IV*

$$X_1 = -11.27 - 0.357\ X_{21} - 0.765\ X_{22}$$
$$(0.080)\dagger \quad (0.172)\dagger$$
$$R^* = 0.760\ R^2 = 0.577$$

Components added to $R^2$ at each step:

0.420 $X_{21}$ small commercial farms
0.157 $X_{22}$ small scale farms

0.577

*Significant at the 99 per cent level.
†Figures in brackets represent the standard errors of the regression coefficients.

Apart from slight variations in degree of over- or underexplanation, the map showing the residuals from regression of this Model (Figure 6) does not differ greatly from the general pattern of performance maps of the previous models. Two notable exceptions are, however, Census Divisions 3 and 6 of Manitoba. These are the only areas overpredicted in every previous model but underpredicted in Model IV. Further research is needed to obtain a greater insight into the complexities of the socio-economic conditions of these two areas to account for such variations.

*Model V*

All the 15 independent variables retained in the study are included in Model V in order to establish the relationship that all combined have with depopulation (Regression A). The coefficient of multiple determination ($R^2$) for this Model is 0.700 and the coefficient of multiple correlation (R) is 0.837.

The over-all efficiency of this Model can be increased by eliminating variables in such a way as to obtain the largest values of $R^2$ and R through the smallest number of variables. By retaining the first four of the list and eliminating the rest, the values of $R^2$ and R would decrease insignificantly (to 0.618 and 0.786 respectively) while more than two-thirds of the variables would be deleted at the same time.

Once again small commercial farms ($X_{21}$) is at the top of the list, followed by small scale farms ($X_{22}$) as the most effective predictors explaining depopulation of farms. Rented area ($X_3$), and paid labour ($X_{11}$) complete the list of the four most relevant variables.

*Multiple regression equations, Model V*

*Regression (A)*

$$X_1 = 28.620 -$$
$$-0.300\ X_{21} - 1.201\ X_{22} + 0.009\ X_3 - 0.467\ X_{11} -$$
$$(0.224)\dagger \quad (0.570)\dagger \quad (0.009)\dagger \quad (0.704)\dagger$$
$$-0.011\ X_{13} + 0.038\ X_{12} - 1.229\ X_{14} + 0.921\ X_{20} +$$
$$(0.005)\dagger \quad (0.034)\dagger \quad (0.767)\dagger \quad (0.531)\dagger$$
$$+0.196\ X_8 - 1.790\ X_{15} + 0.069\ X_5 - 2.387\ X_{18} +$$
$$(0.435)\dagger \quad (2.130)\dagger \quad (0.062)\dagger \quad (2.021)\dagger$$
$$+4.104\ X_{17} - 0.031\ X_4 + 0.088\ X_{19}$$
$$(4.303)\dagger \quad (0.040)\dagger \quad (0.156)\dagger$$

$$R = 0.837 \quad R^2 = 0.700$$

Components added to $R^2$ at each step:

0.4203 $X_{21}$ small commercial farms
0.1571 $X_{22}$ small scale farms
0.0222 $X_3$ rented area
0.0188 $X_{11}$ paid labour
0.0082 $X_{13}$ rent paid
0.0330 $X_{12}$ taxes paid
0.0037 $X_{14}$ total capital value
0.0078 $X_{20}$ large commercial farms
0.0046 $X_8$ part-time farm operators
0.0046 $X_{15}$ value of machinery
0.0039 $X_5$ farm land cropped
0.0039 $X_{18}$ capital return
0.0048 $X_{17}$ value of products sold
0.0051 $X_4$ farm land improved
0.0024 $X_{19}$ commercial farms

0.7004

*Significant at the 99 per cent level.
†Figures in brackets represent the standard errors of the regression coefficients.

The multiple regression equation with those first four indicators is given in Regression B.

Figure 7 presents the spatial distribution of residuals from this regression* in the same terms as from the previous regressions ($Y - Y_c$). Most areas (in fact three-quarters of all census divisions and areal divisions) are well predicted in this context. The strongly underpredicted areas are the northern and southwestern fringes of Alberta and Areal Division 26 of Saskatchewan, and coincide with areas of heavy losses of farm population. Most overpredicted areas had only moderate population losses.

*All performance maps of Model V are based on Regression (A).

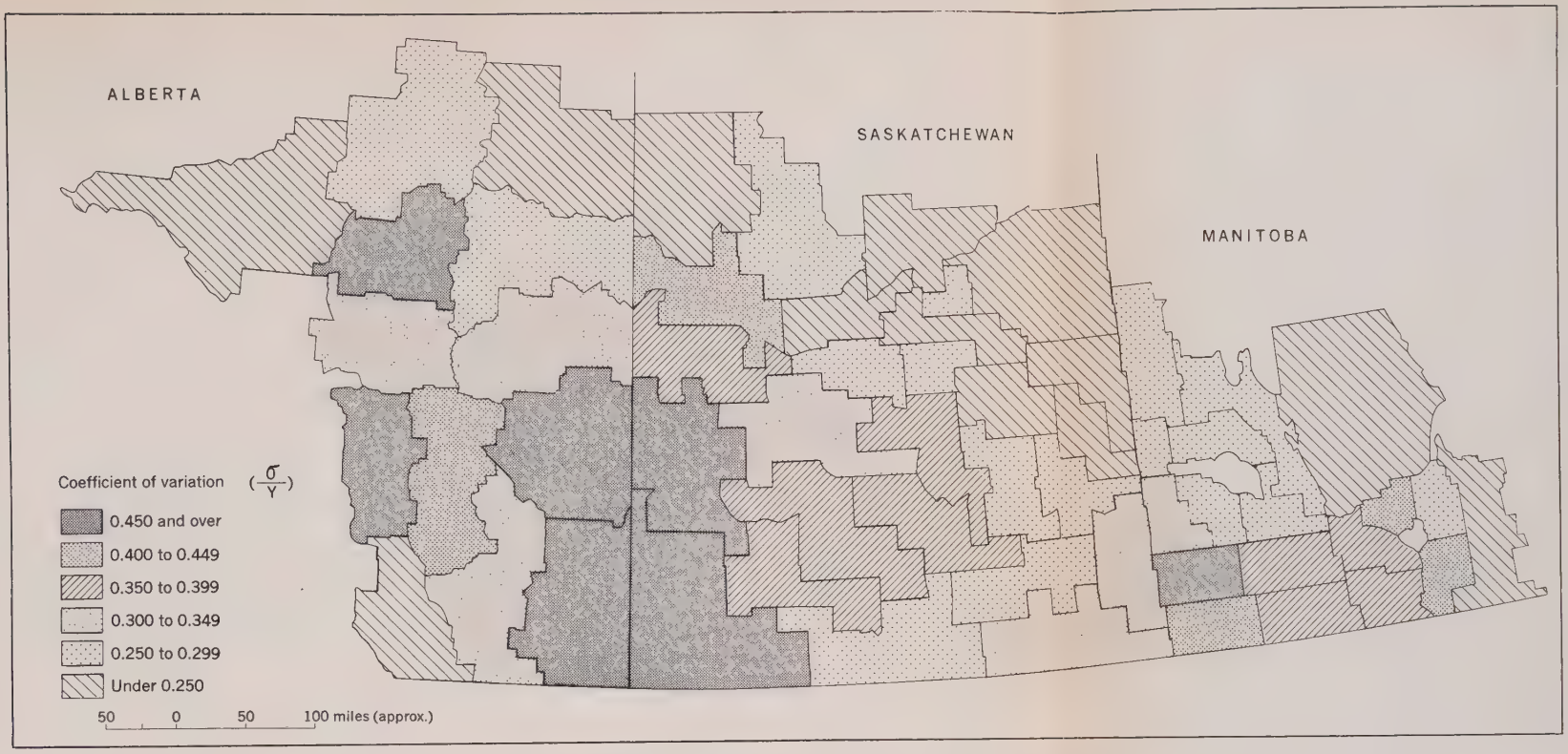


FIGURE 2. $\sigma$ = standard deviation; Y = actual value of apparent net outmigration.

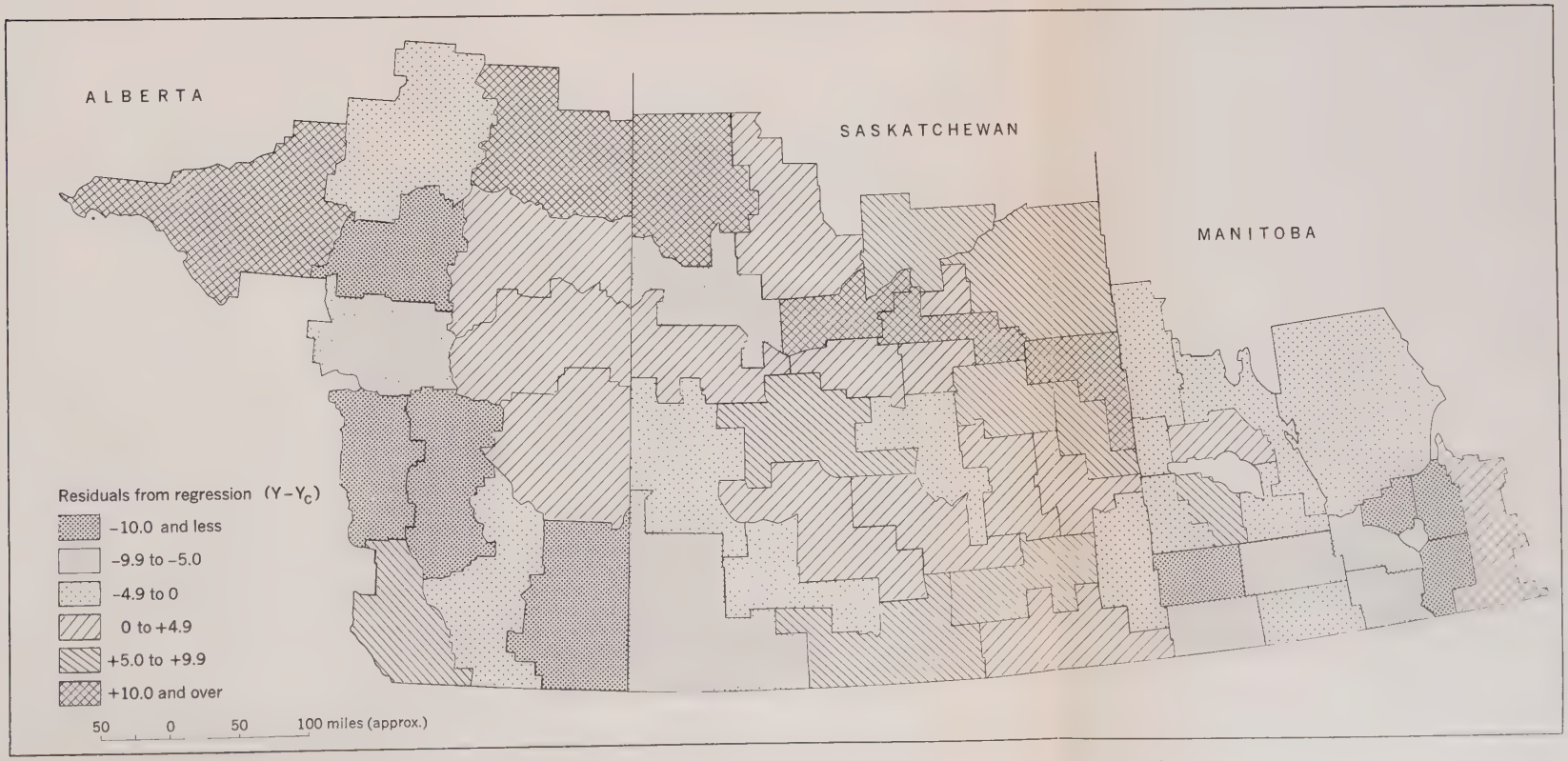


FIGURE 3. Model I (farm land cropped, part-time farm operators, rented area).

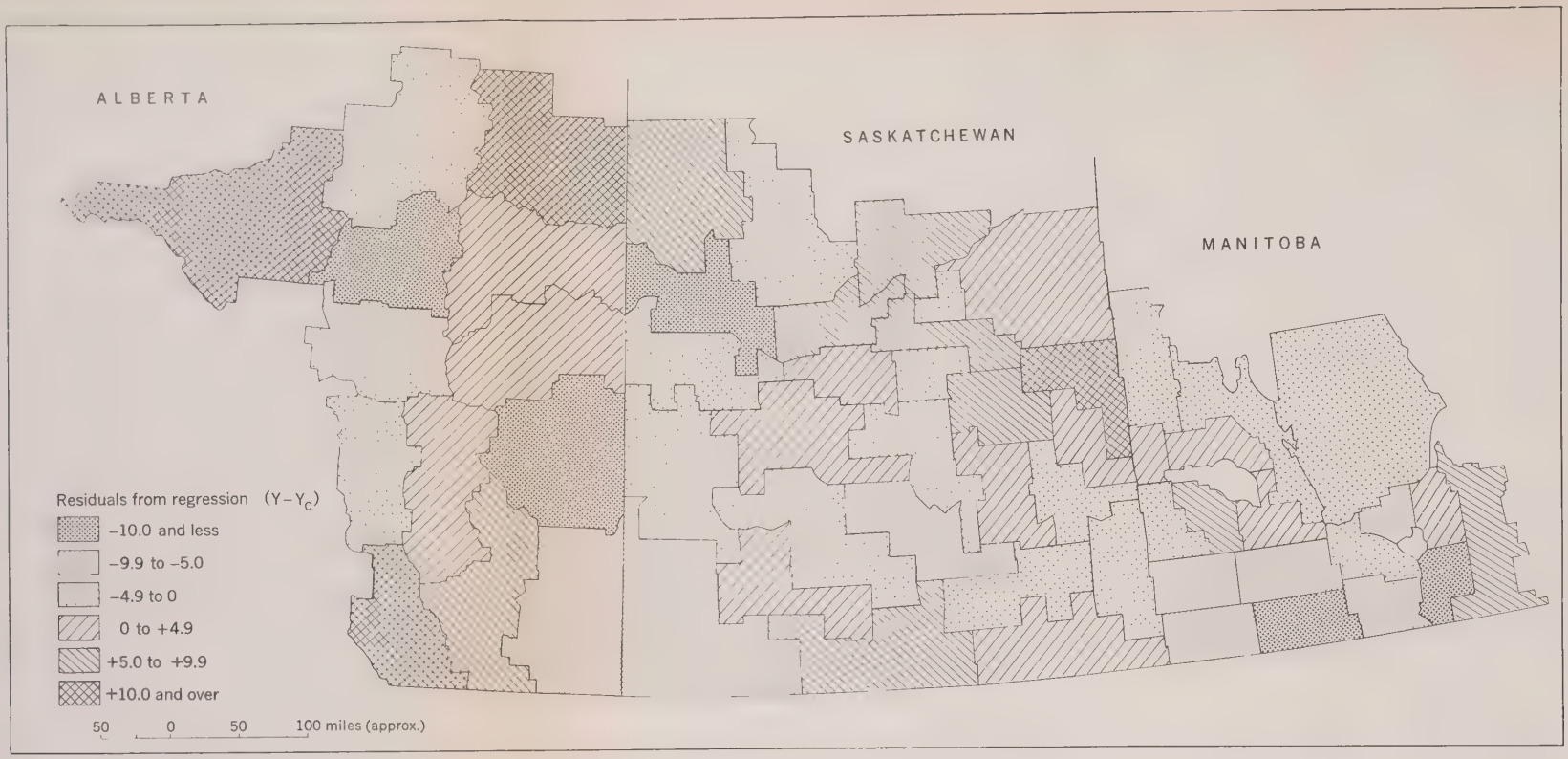


FIGURE 4. Model II (paid labour, taxes paid, rent paid).

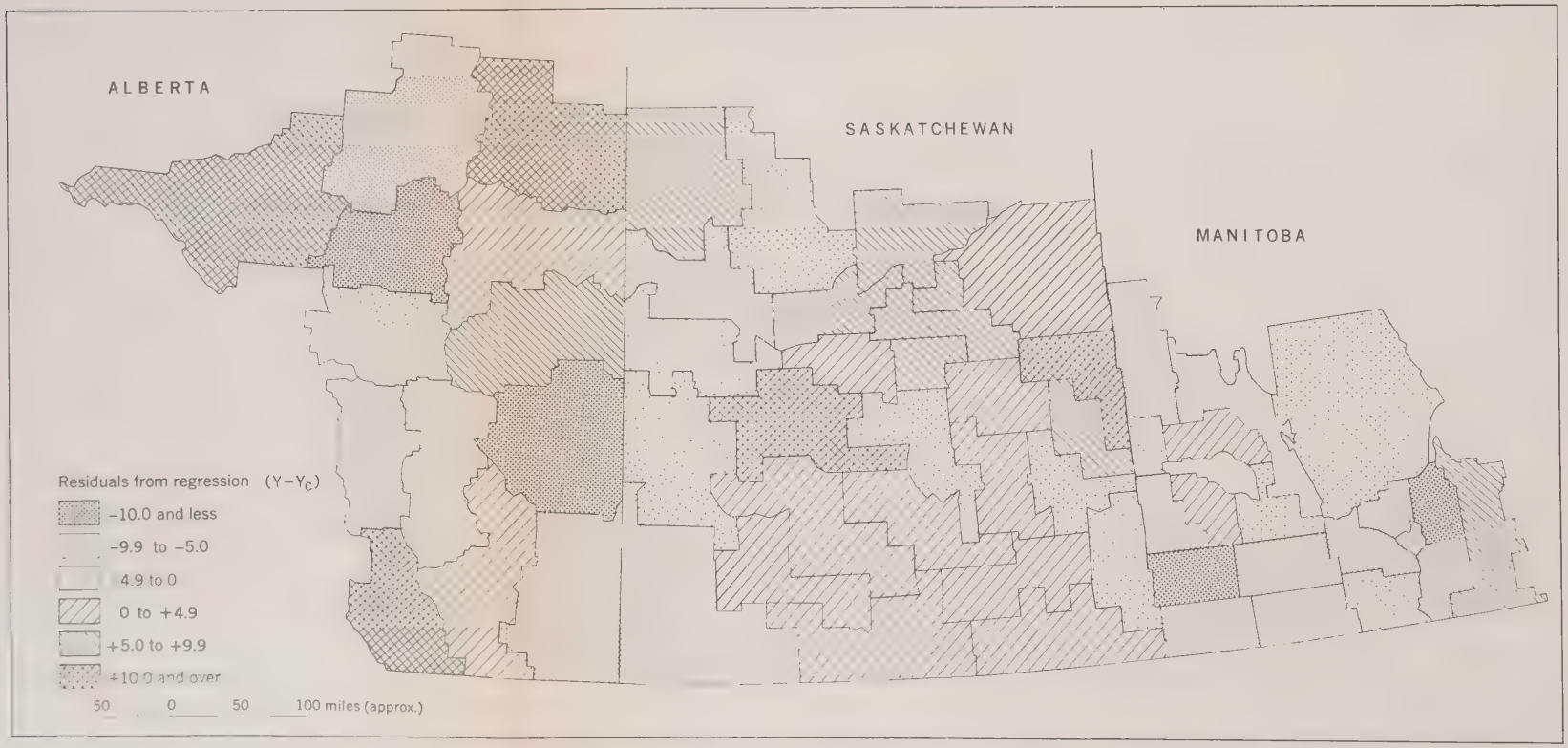


FIGURE 5. Model III (value of products sold, return on capital, total capital value, value of machinery).

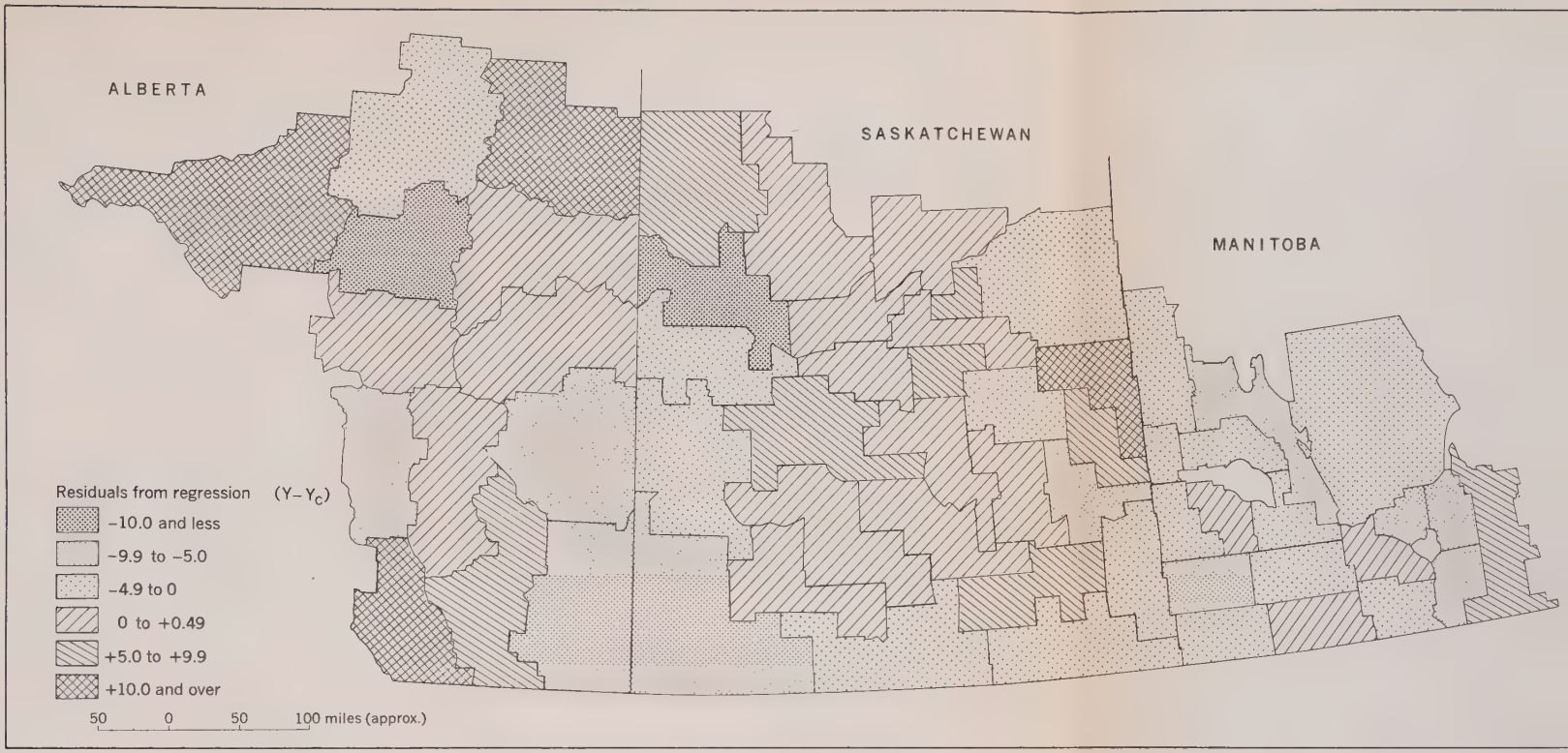


FIGURE 6. Model IV (small commercial farms, small scale farms).

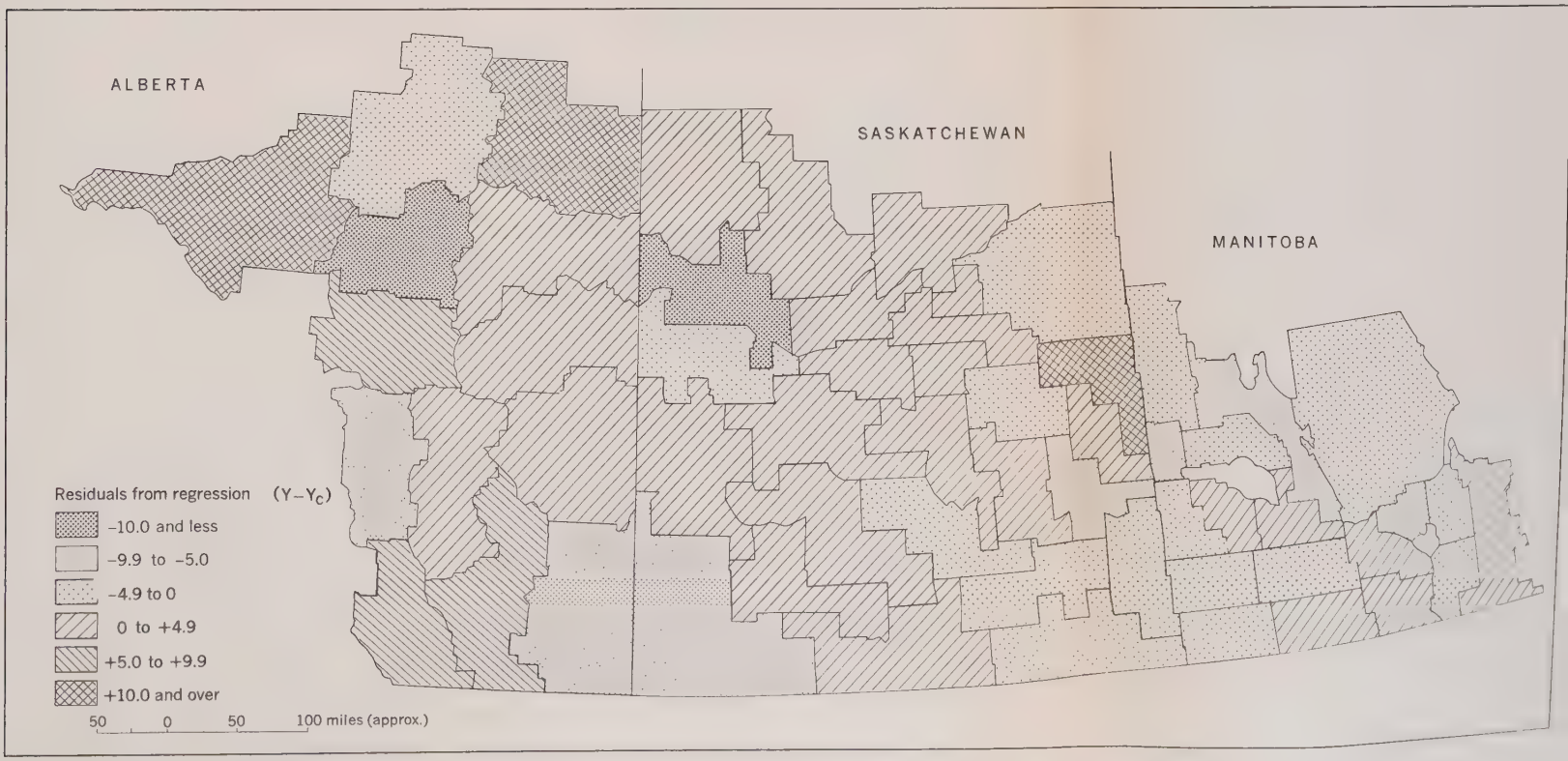


FIGURE 7. Model V: map A (all independent variables included; residuals given in absolute terms).

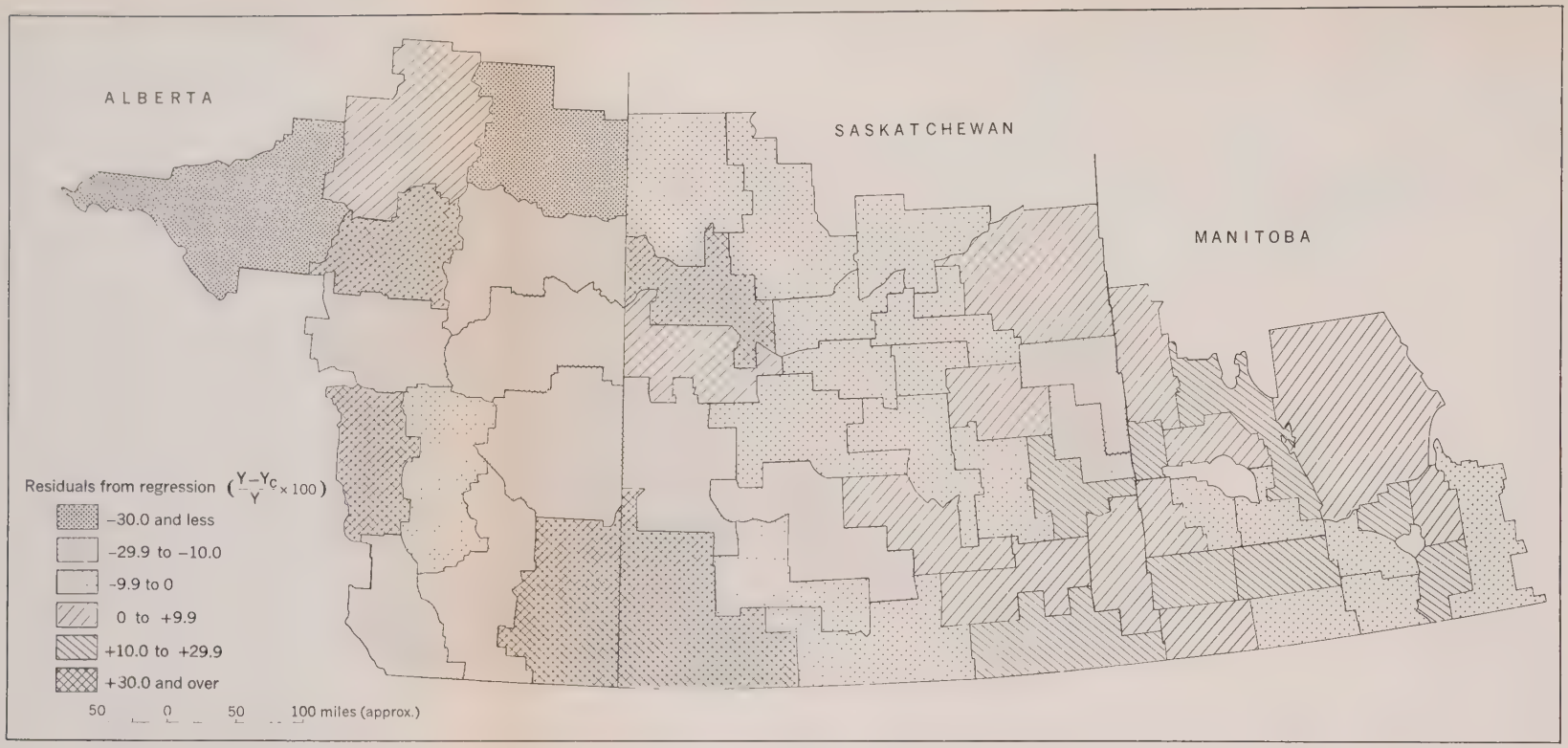


FIGURE 8. Model V: map B (all independent variables included; residuals given in percentages).

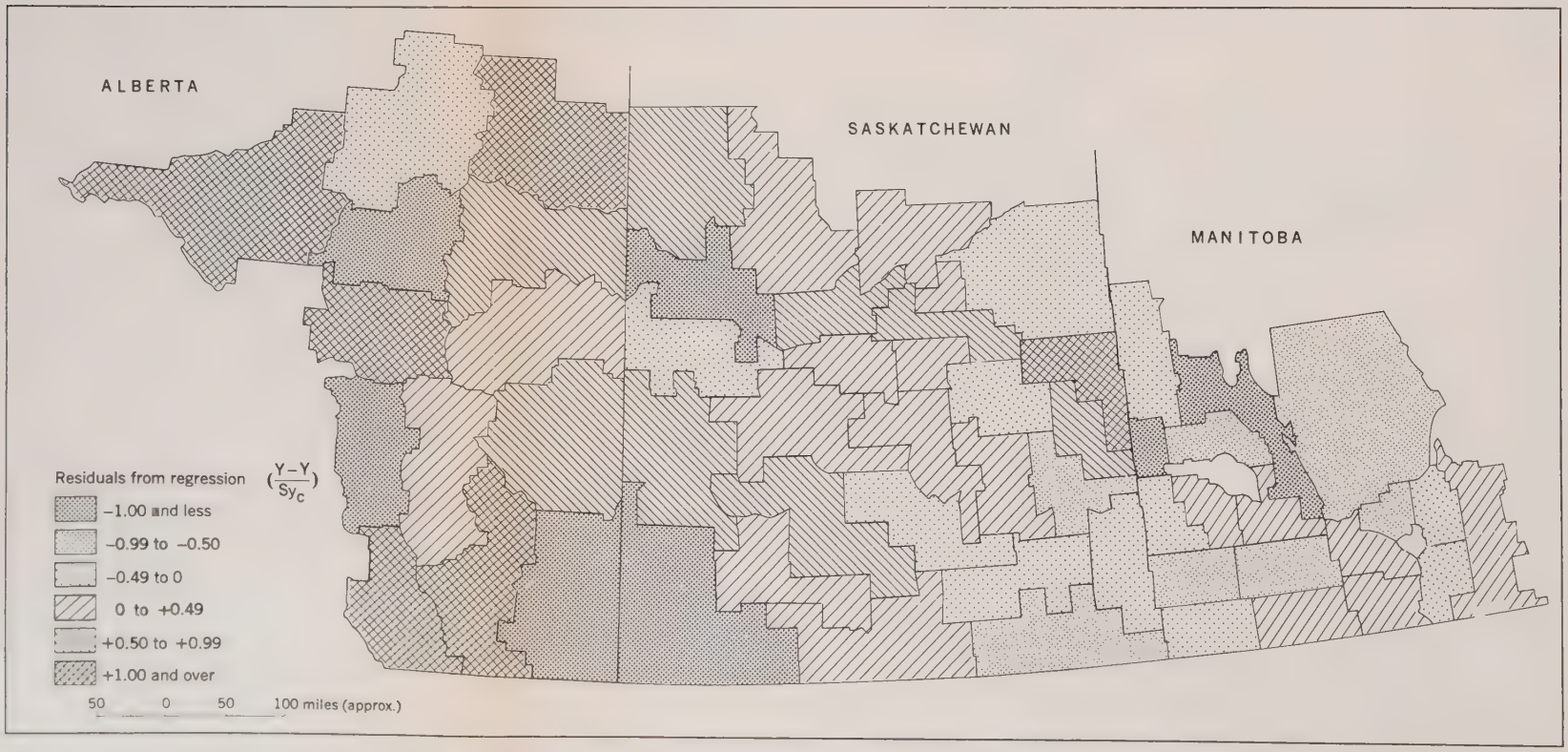


FIGURE 9. Model V: map C (all independent variables included; residuals given in terms of the standard error of estimate).

*Regression (B)*

$X_1 = -4.455 -$
$-0.455\ X_{21} - 0.758\ X_{22} + 0.009\ X_3 - 0.636\ X_{11}$
$(0.103)\dagger \quad (0.185)\dagger \quad (0.004)\dagger \quad (0.402)\dagger$

$R^* = 0.786\ R^2 = 0.618$

Components added to $R^2$ at each step:

0.420 $X_{21}$ small commercial farms
0.157 $X_{22}$ small scale farms
0.022 $X_3$ rented area
0.019 $X_{11}$ paid labour
———
0.618

*Significant at the 99 per cent level.
†Figures in brackets represent the standard errors of the regression coefficients.

Figure 8 presents the distribution of regression residual $(Y - Y_c \div Y) \times 100$. This residual gives the magnitude of the difference between observed and estimated values of depopulation for each area relative to the observed value.

The spatial pattern of this residual is markedly different from that of the previous type. One reason is the difference between the algebraic nature of the two types of residual. For any given area the sign of $Y - Y_c/Y$ may not be the same as $Y - Y_c$. In this specific case of Model V, in fact, signs for all the areas are different. Furthermore, residuals $Y - Y_c$ for any two areas may be identical but when divided by different observed values for each of the two areas the resulting ratio will be different (large ratio if divided by a small Y and small ratio if divided by a large Y). The map of residual $Y - Y_c/Y$ provides a better differentiation between areas as to the degree of explanation Model V can offer. In this context only somewhat less than 60 per cent of all areas are well predicted as against 75 per cent when $Y - Y_c$ is used (Figure 7). Hence this type of residual is more suitable for mapping if the values of $Y - Y_c$ are in most cases small.

Mapping of differences between observed and computed values of the dependent variable can also be facilitated if they are expressed in terms of the standard error of estimate ($S_{y_c}$). Figure 9, portraying the distribution of this residual $(Y - Y_c/S_{y_c})$ shows an even 50 per cent of all areas well predicted. Since the value of $S_{y_c}$ is always positive there is no basic change in the spatial pattern of this residual and it can directly be compared with that of $Y - Y_c$ (Figure 7). A further advantage of using this residual is that the relative rarity of individual values can easily be determined. Since it is known that a $Y - Y_c/S_{y_c}$ value equal to or greater than 2.6 will occur less than one per cent of the time (Thomas, p. 22), areas falling into this category can be designated for further investigation. On Figure 8, Census Divisions 12 and 14 of Alberta are such cases.

## SUMMARY AND CONCLUDING REMARKS

Although it cannot be applied without difficulty, multiple regression analysis has been found a useful tool for investigating spatial relationships between demographic process and economic characteristics. This study, while in various measures verifying the suspected interaction between the process of depopulation and certain economic characteristics of areas, established the relative importance of economic attributes and their collective relationship with depopulation as defined in the context of model designs. It also explored the geographic distributions of these average relationships.

The usefulness of this technique can be increased by including further variables of the following nature:

(a) Composite variables*, incorporating critical demographic, social and economic characteristics.

(b) Variables reflecting space-relations (e.g., distance to larger urban centres as places of potential job opportunities, etc.).

(c) Variables indicating historical developments (e.g., the time elapsed since an area was first settled, etc.).

(d) Variables relevant to farm family incomes from all sources (and not only farm incomes alone). The analyses should be carried out with a view to the cost of financing relocation.

In the light of the social and economic prospects facing Canada in the remaining years of the 1960's, conditions for large scale off-farm migration associated with abandonment of agriculture as an industry will likely be less favourable than during the 1950's. Among others, two specific aspects of prospective development will act strongly against it:

(1) The rate of expansion of the labour force will be extraordinarily high during this period and since the full force of the postwar "baby-boom" will be felt, a higher proportion of this

*In the same sense as Berry applied (1965).

increase will consist of young (20-24 years) people than ever before in Canada's history. The First Annual Review of the Economic Council of Canada (1964, p. 33) states: "Whereas the male labour force in this age group increased by only 25,000 in the decade of the 1950's, in the 1960's it will increase by 270,000, or more than ten times as much. In other words, the average increase for this group each year will exceed the increase which took place over the whole of the last decade."

(2) As automation continues, the demand for the young and well-educated will increase to the obvious disadvantage of those whose age, education and other social attributes do not make them adaptable to specialized job training.

As an alternative to off-farm migration, part-time farming and off-farm employment will likely increase, resulting in economically more diversified areas than at present. Since the cost of relocation is also likely to increase, relatively more migrants will be recruited among the presently full-time, smaller commercial farm operators than among those who are already part-time operators of usually small scale farms. Part-time farm operators may also have a decreased propensity to migrate since they have already established alternate sources of income. As the most important single factor inducing migration is economic opportunity elsewhere (Sjaastad, 1961, p. 12), off-farm migration will be higher at times of general economic prosperity, both urban and rural, than at times of recession. Migration will also be more intensive from areas which achieved a lower degree of farm population balance (generally underpredicted areas on the performance maps of this study) and less intensive from other areas.

## ACKNOWLEDGMENTS

The writer would like to acknowledge the kind assistance of the staff of the Census Division and the Scientific Programming Section, Dominion Bureau of Statistics in providing tabulations of census material and computations. Sincere thanks are given to Mr. Frank T. Denton of the Dominion Bureau of Statistics, Mr. Gilles Paquette of Carleton University and Mrs. Eva Tihanyi of the Centre for Community Studies, University of Saskatchewan, for their valuable comments and advice in the preparation of the manuscript.

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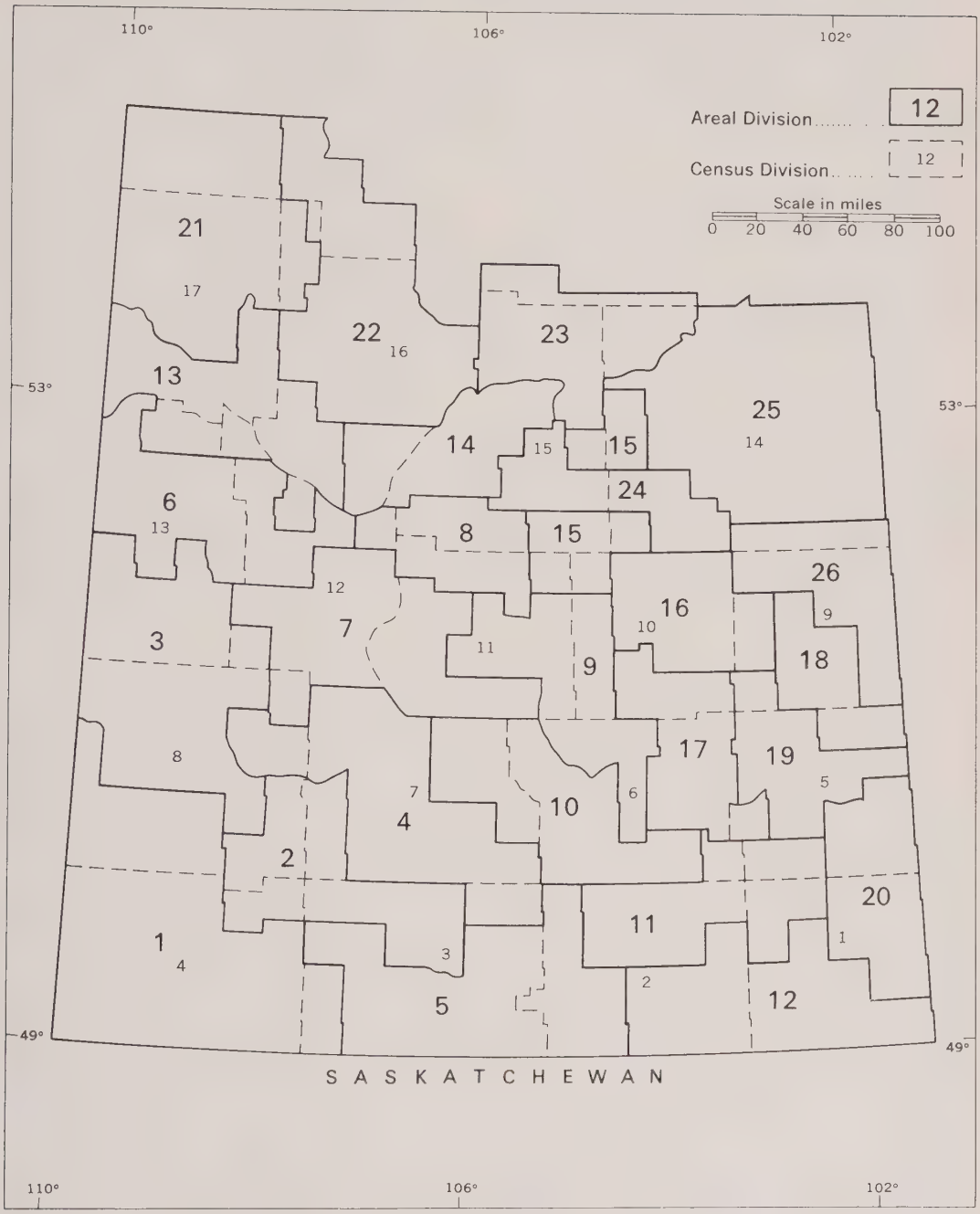
*Appendix I*


110°
106°
102°
Areal Division 12
Census Division 12
Scale in miles
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SASKATCHEWAN

$X_1$ "Depopulation": the difference between actual 1961 census population on farms and the "expected" farm population of 1961. The "expected" farm population was computed by adding the estimated births and deducting the estimated deaths from the 1951 actual farm population.

$X_3$ "Rented area": total farm area rented by the farm operator whether the rent was in cash or kind.

$X_4$ = "Farm land improved": total area under crops, improved pasture, summer fallow and other improved land.

$X_5$ = "Farm land cropped": total area of cropland sown or to be sown for harvest in 1961.

$X_8$ "Part-time farm operators": farm operators reporting any kind of work including agricultural work off the operator's farm. (Percentage of all farm operators.)

$X_{11}$ "Paid labour": hired agricultural labour in terms of male labour weeks per farm.

$X_{12}$ = "Taxes paid": for the twelve month period preceding the 1961 census.

$X_{13}$ = "Rent paid": in cash or kind for the period of June 1, 1960—May 31, 1961.

$X_{14}$ = "Total capital value": land and buildings, machinery and equipment (including automobiles), livestock and poultry, regardless of tenure. The value reported was to be an estimate of the market value, not the original replacement or assessed value.

$X_{15}$ = "Value of machinery": values of machinery still in use were to be reported.

$X_{17}$ = "Value of products sold": revenues representing the value of all agricultural products sold from the farm including products traded or exchanged during the 12-month period before the census or in the calendar year of 1960.

$X_{18}$ = "Return per unit of capital": the ratio between the "value of products sold" and the "total capital value".

$X_{19}$ = "Commercial farms": proportion of all commercial farms (reporting annual sales of agricultural products of $1,200 or more) of all census farms (an agricultural holding of one acre or more with annual sales of agricultural products of $50 or more).

$X_{20}$ = "Large commercial farms": proportion of farms with sales of $10,000 or more of all commercial farms.

$X_{21}$ = "Small commercial farms": proportion of farms with sales of $1,200—$3,749 of all commercial farms.

$X_{22}$ = "Small scale farms": proportion of farms with sales of $50—$1,199 of all census farms.

GEOGRAPHICAL BULLETIN, VOL. 7, NOS. 3 AND 4, PP. 203-211, 1965

# THE LAND-USE SURVEY OF THE NIAGARA PENINSULA—A CRITICAL REVIEW

*L. G. Reeds**

ABSTRACT

A critical appraisal of the Niagara land-use survey is presented. The inadequacies of the 1:50,000 scale maps in depicting land-use patterns in the fruit belt are demonstrated by comparison with sample studies on a larger scale. The value of the land-use maps is discussed and illustrated by reference to the Niagara West sheet. The need for further study of mapping techniques and integration of land-use surveys with a comprehensive land inventory is emphasized.

RÉSUMÉ

L'auteur donne un aperçu critique de l'utilisation des terres dans la péninsule de Niagara. En faisant une comparaison avec des études de cartes choisies à plus grande échelle, il prouve que les cartes au 1/50,000 représentent insuffisamment les différents types d'utilisation des terres dans la zone de fructiculture. Il traite de la valeur des cartes d'utilisation des terres et la démontre par rapport à la feuille de Niagara Ouest. Il souligne qu'on a besoin de poursuivre l'étude des méthodes de cartographie et de coordonner les études sur l'utilisation des terres avec l'établissement d'un inventaire complet et détaillé.

## INTRODUCTION

The land-use survey of the Niagara peninsula is part of a national program of land-use mapping begun by the Geographical Branch in 1950. The production of land-use maps was undertaken with the expectation that the information would contribute to a solution of both national and local land-use problems (Nicholson, Cornwall and Raymond, 1961).

In the survey of the Niagara peninsula, direct field mapping and air-photo interpretation were carried out by the Ontario Community Planning Branch and the Geographical Branch during the summers of 1959 and 1960. A slightly modified World Land Use Classification was adopted because it provided inclusive categories and was considered to be appropriately designed to meet the variable conditions of Canada (Watson, 1952). Eleven maps in colour have been published on the scale of 1:50,000 since 1960.

All land-use maps have severe limitations. They fail to give an accurate record of the true picture of land use, particularly where the patterns of use are complex. They reveal little about the inherent qualities of the land and cannot be regarded a reliable basis for evaluating land capability. They may fail to reveal the exact economic aspects of agricultural development because in certain types of farming the actual use of the land may not be associated at all with the primary economic activity. In these instances, the farm is used only as a base of operations and practically all of the feed used is purchased. Because of the generalizations involved in the production of small scale land-use maps, they are not reliable for correlation with the physical features of the landscape. Oftentimes land-use surveys are initiated without proper consideration for the fundamental objectives of planning and as a result do not provide the necessary data that are essential for effectuating constructive adjustments in problem areas.

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*Dr. Reeds is a member of the Department of Geography, McMaster University. This paper was prepared while he was working as a temporary member of the Geographical Branch during 1964–65.

When it was pointed out that the Niagara land-use maps had not been used to any extent by local agricultural scientists, planners, conservationists or foresters, the writer decided to undertake a critical examination of them. This was carried out by studying the maps and their method of preparation and production, by checking them in the field and by comparing them with other maps produced using different scales and systems of classification.

The purpose of this paper is to present a critical appraisal of the Niagara land-use maps, a description and interpretation of a representative sheet and a discussion of alternative methods. Because of the writer's interest in agriculture, the major criticism will be directed at the rural aspects of the maps.

## LIMITATIONS OF THE LAND-USE MAPS

The Niagara land-use maps vary considerably in accuracy and in places exhibit careless field observations.

Because of the small scale and limited number of categories, the maps fail to depict the complexities of the agricultural scene in the fruit belt. Vineyards, horticulture and tree fruits cannot be mapped satisfactorily in certain local areas because of the common practice of inter-culture of crops. A few rows of cherry trees may occupy a roadside location with vineyards behind. Small vineyards may also be interspersed among larger orchards occupying pockets of heavier textured or more poorly drained soil. Vegetables may be grown as inter-row crops in young orchards. This practice enables the farmer to gain a return from the land during the interim period before the fruit trees reach the bearing stage. Other fruit farmers grow small acreages of vegetables in order to diversify their sources of income and to utilize labour and equipment at times when fruit requires little attention. Peaches are often grown on small sandy knolls in a clay area which may be devoted to vines, pears, plums or sour cherries. In the mapping of horticulture, much generalization is necessary and in many cases the size of the fields is smaller than the minimum size of unit that can be shown on a 1:50,000 map.

Turning to the areas where general field crops are predominant, the maps are somewhat more adequate, although many interesting details and important differences are not shown. An old, run-down orchard, which may even be abandoned, commands the same colour symbol as a most productive field of young fruit trees. A field of timothy choked with weeds and producing little of value cannot be distinguished from a lush crop of alfalfa or mixed clovers which may yield more than three tons of nutritious hay per acre. The over-all pattern of hay, grain and pasture appears artificially uniform since the minor field-to-field variations are not shown. The maps do not reveal the fact that many hay fields are pastured after harvesting and that much of the open woodland is pastured throughout the summer. Field observations indicate that the differences between open and scrub grassland and between hay and open grassland are often negligible. Furthermore, the distribution pattern of open grassland can easily be misunderstood. In the vicinity of Hamilton and other urban centres, open grassland is usually held by speculators and is entirely lost to agriculture whereas in the rural areas it may only be temporarily idle. Field surveys indicated that considerable areas mapped as open grassland in 1960 were being cultivated in 1964, as in the case of the transition to corn growing on the light-textured soils east of Dunnville.

The maps do not treat non-farm residences consistently as in some places individual houses are shown while in others entire hamlets have been omitted. Summer cottages have been included in the residential category leaving the reader with the impression that all are occupied on a permanent basis. Considerable areas along Lake Erie, which are now covered by water, have been mapped as unproductive land in order to fill in the space between the present and former shorelines. This was the means adopted of coping with an inaccurate base map.

Because of the small map scale and limited number of categories employed, the patterns of land use depend to a great extent on the judgment of the observer. Since the field worker makes many generalizations daily and since several observers were involved, interpretations varied considerably. The subjective quality of the survey was revealed by the study of sample blocks of land in the field. Figures 1 and 2 are examples of these sample studies carried out by the writer and his graduate students in 1963 and 1964. The first example compares an area in Concession I, Clinton Township mapped by Goodman (1965) on the scale of 1:8,000 with the 1:50,000 series. The larger scale map employs 15 categories while the 1:50,000 map has only three, tree fruits and

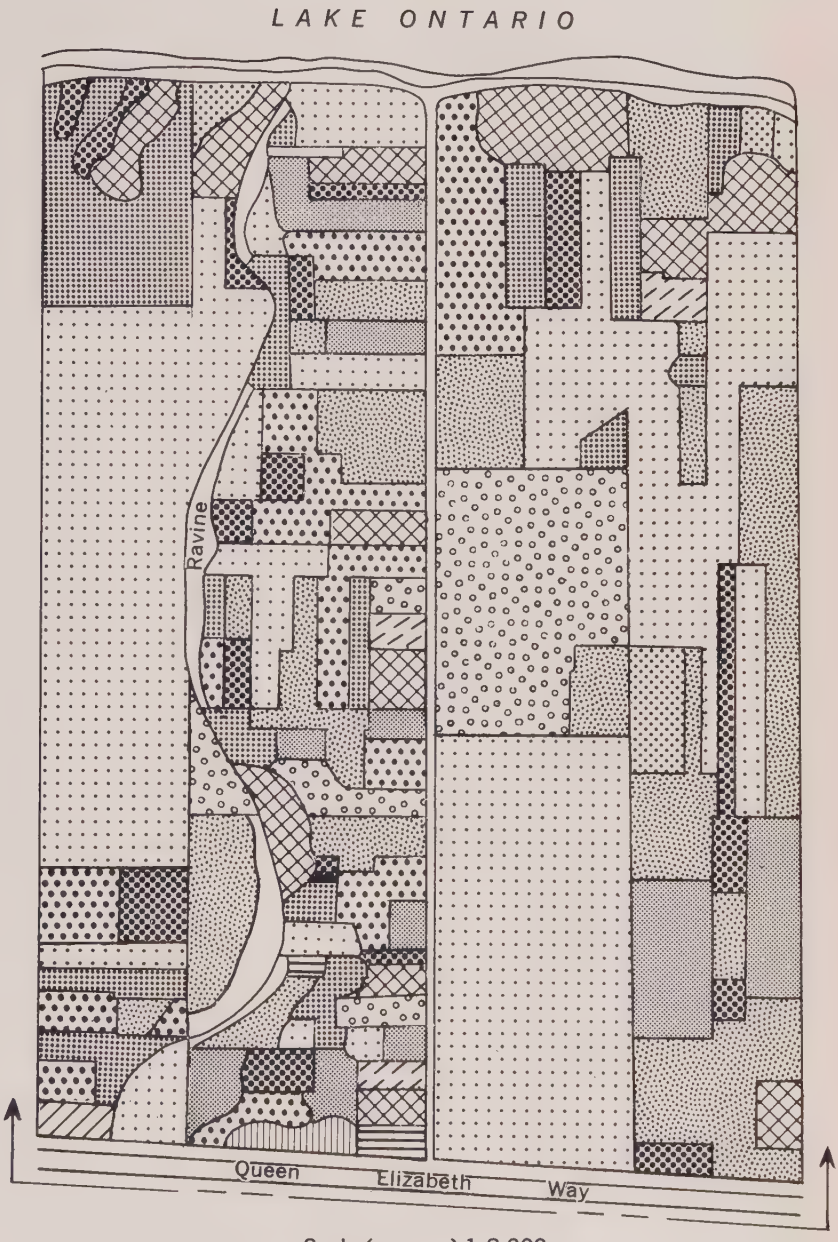
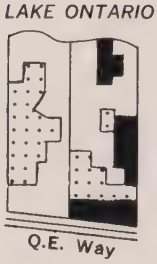



FIGURE 1. Land-use sample study in the Niagara Fruit Belt. Inset map

'ee fruits and small fruits
ineyards
orticulture




Scale 1:50,000

REE FRUITS

pples
herries
eaches
ears
lums
ixed tree fruits

INEYARDS AND SMALL CROPS

rapes
mall fruits
egetables

ROPLAND

ay
lle grassland
pen Woodland
rmsteads, residences

shows same area on 1:50,000 scale.

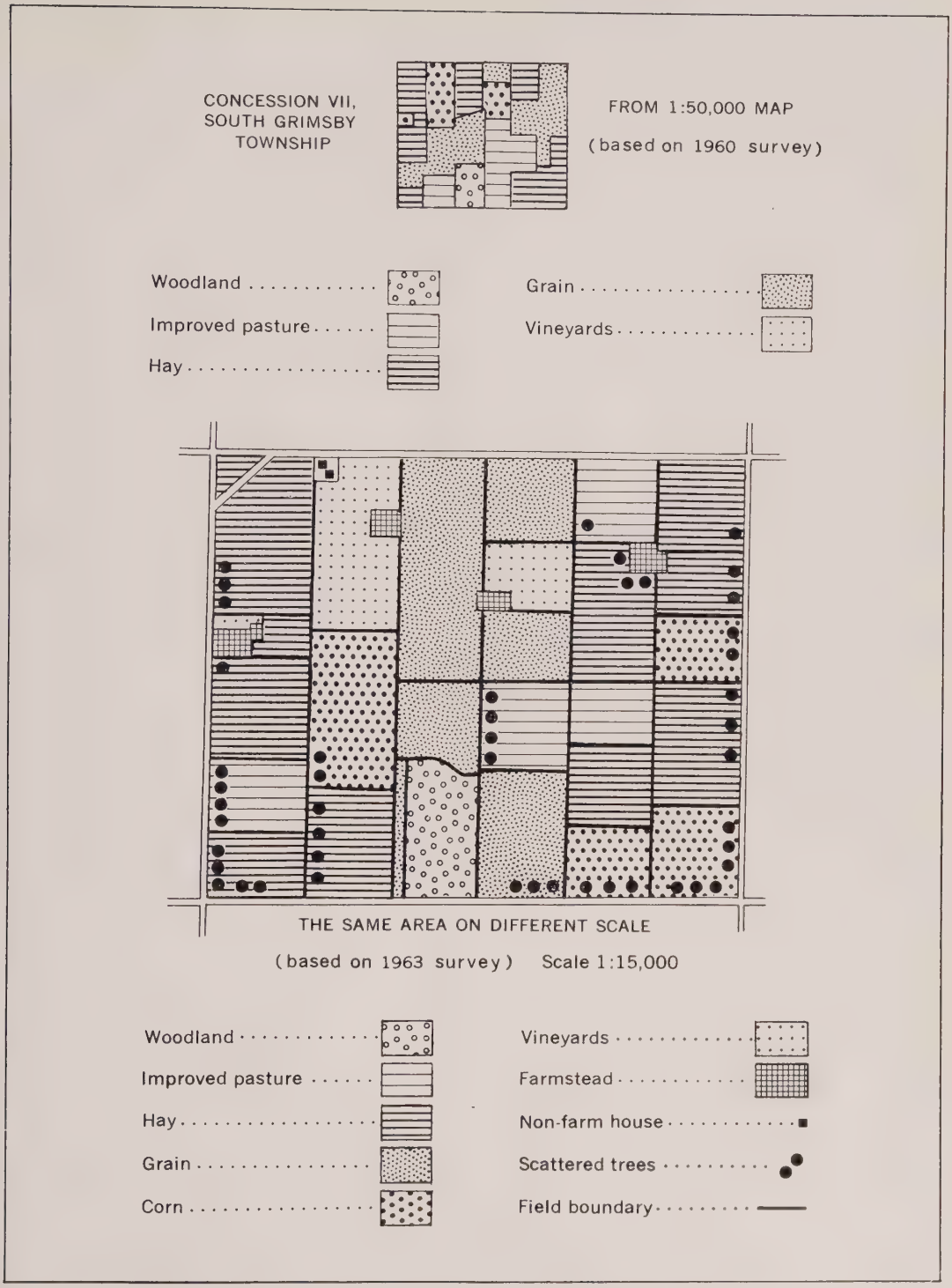



FIGURE 2. Land-use sample study in mixed farming area. Inset map shows the more generalized pattern on 1:50,000 scale.



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small fruits, vineyards and horticulture. The 1:8,000 map portrays the intimate detail of the association of different types of tree fruit, small fruit, vegetables and vineyards. This gives the reader a better insight into the economy of fruit farming as the actual "ground" pattern is clear and the exact acreage of each crop can be computed. The horticulture mapped in the southeastern corner of the 1:50,000 map is a direct error in plotting since interviews revealed that this parcel of land had not been used for that purpose when the survey was made in 1960. The comparison of these maps is convincing proof that the 1:50,000 scale is too small for depicting the intricate land-use patterns of the fruit belt.

Figure 2 is another comparison with a map based on a survey carried out in 1963, which uses the scale of 1:15,000. It represents a sample from the mixed farming areas of the peninsula. The larger scale map presents a more accurate and clearer picture of the land-use pattern. It shows the actual field boundaries, the exact location of farm buildings and even such an interesting and distinctive feature of the agricultural landscape as the distribution of scattered trees. The large scale map suggests the need for a separate category for ensilage corn. These maps indicate the local variations in land use which may occur from year to year but the relatively little change which takes place in the overall pattern. Table 1 reveals the stable position occupied by hay, grain, and pasture in the mixed farming economy. This sample study points up the fact that the 1:50,000 scale is more adequate for showing land use in the general farming areas than it is for representing the complexities of the agricultural landscape of the fruit belt.

*Table 1*

| *1:50,000 map* | | *1:15,000 map* | |
|---|---|---|---|
| | Percentage of total area | | Percentage of total area |
| Hay | 40 | Hay | 40 |
| Grain | 30 | Grain | 25 |
| Pasture | 18 | Pasture | 10 |
| Vineyards | 7 | Vineyards | 8 |
| Woodland and other uses | 5 | Ensilage corn | 12 |
| | | Woodland and other uses | 5 |

The land-use maps reveal little about the organization aspects of agriculture since there are no symbols referring to crop rotations, to farm boundaries, or to whether the farm is operated on a full or part-time basis or by an owner, tenant or manager. Almost 25 per cent of the farms of the peninsula are part-time, residential, or farms whose value of products sold is less than $250 annually. The maps do not give the location of any of these types of farms.

Field observations revealed changes in the agricultural land use of the peninsula. The vineyard acreage is increasing steadily in areas immediately to the south of the escarpment. Corn for grain is becoming increasingly important on the well-drained soils in the western parts of the peninsula. Urban encroachment on agricultural land is continuing in the Ontario lakeshore plain. Scrub grassland is gradually reverting to woodland in many places while part-time farming with its accompanying extensive uses of land is increasing everywhere and especially in Lincoln, Wentworth and Haldimand counties. Canning crops are declining in importance in the Fonthill region. The trend to further specialization in orchards, vineyards, and horticulture is continuing in the eastern parts of the fruit belt. Because of these changes, the land-use maps which are based on recent surveys, are already in certain respects, obsolete.

## VALUE OF THE LAND-USE MAPS

Because of deficiencies and inaccuracies can the land-use survey of the Niagara peninsula have any practical or theoretical value?

A mosaic of the Niagara land-use sheets presents a picture of geographic patterns which cannot be seen as clearly by any other means, unless the landscape is seen with binoculars from a hovering, high-flying plane. The major areal differences in land use can be seen at a glance from the maps and closer examination reveals a variety of patterns. After only a brief scrutiny an experienced observer can easily identify at least twenty, distinctive land-use types in the peninsula. Such a map of land-use types contributes in a rather important way to an understanding of the development of this region. The varying uses of land can be related to each other and to the broad aspects of both the physical and cultural environments. The maps provide a basis for comparison with patterns of use in other parts of Canada and in other countries of the world. The location and extent of urban development is clearly seen

and the interaction of urban and agricultural forces can be deduced.

The great contrast between the specialized agricultural development of the lowland south of the escarpment and the patterns of use associated with mixed farming and dairying in the dip-slope plain is clear. The transitional region along the brow of the escarpment with its scattered vineyards alternating with hay, grain and pasture and the horticultural island surrounding Fonthill are easily identified. The green and orange pattern of woodland and grassland in the Tuscarora Indian Reserve surrounded by the more intensive land uses of neighbouring townships stands out sharply. The Welland East sheet with its large area of grasslands testifies to the problems of coping with the poorly drained, low-lying, intractable clays and to the prevalence of extensive uses which have accompanied the development of part-time farming. The predominant green in Seneca, Caistor, Cayuga and Canborough townships is indicative of the influence of poor drainage and of the effects of a less accessible location and later initial settlement. The patches of blue amidst large blocks of orange to the east of Dunnville suggest the tendency to use the bulk of these relatively poor soils extensively and the traditional custom of using small areas for market garden and canning crops. The higher proportion of hay in the poor general farming regions in the southeastern parts of the peninsula is obvious. The greater importance of grain in the western regions where the soils generally give better yields and where there is a great concentration of livestock is another interesting relationship. The absence of large areas of woodland in Ancaster, Glanford and Binbrook townships reflect, in part at least, the more intensive uses of land that develop in the vicinity of a large metropolitan area provided the soils are suitable. These are several of the distinctive patterns and relationships that an experienced observer can see. A closer examination reveals many minor differences in patterns showing the importance of both physical and cultural factors in determining the precise use made of the land.

Certain authorities have commented on the value of the land-use maps. Bain and Sinclair (1962) have stated:

"that the 1:50,000 maps will prove helpful to provincial agencies as well as to various regional organizations by supplying fundamental data on which development policies and programmes can be based."

Krueger (1962) has stated:

"the maps are an indispensable tool for anyone who is interested in regional description and analysis. They constitute a detailed record of observations from which hypotheses may be formulated. They can be useful in conjunction with a soils map to produce a land use capability classification. Land use mapping is the geographical approach to census taking and if done at times to coincide with a census would provide a means of measuring the impact of population growth upon land uses."

These comments were made without the benefit of a critical examination of the land-use maps in the field and before sufficient time had elapsed to test their validity and applicability. The maps have not been used to any extent by provincial organizations and regional agencies as they do not provide a satisfactory basis for planning. However, they may be useful in the manner suggested by McClellan (1964, p. 55) who points out:

"that comparison of land use maps with those of land capability will assist in the location of areas where changes in land use are desirable."

The broad purpose of the Niagara survey was to compile an orderly compilation of present land use, employing a system applicable to all of Canada. This rather limited and questionable objective was realized. The quality of the cartography compares favourably with that of maps produced by Britain, Japan, Poland and Italy, although the information conveyed is below the standard achieved by some other countries. The Niagara maps have educational value for Canadians and provide those in other countries who are interested in land use with the Canadian approach to this type of mapping.

## AN APPRAISAL OF THE NIAGARA WEST SHEET

The examination of a representative sheet throws further light on the value of the land-use maps. This particular sheet gives a vivid picture of contrasts in land use. The influence of landforms, relief, climate, soils and location is evident.

Specialized agriculture is confined largely to the climatically favoured Lake Ontario plain, to the better-drained undulating soils close to the escarpment, and to the light-textured soils of the Fonthill region. Figures 3 and 4 show the relationship of land use to soil type. The tree fruit specialty type with 77 per cent of its total area



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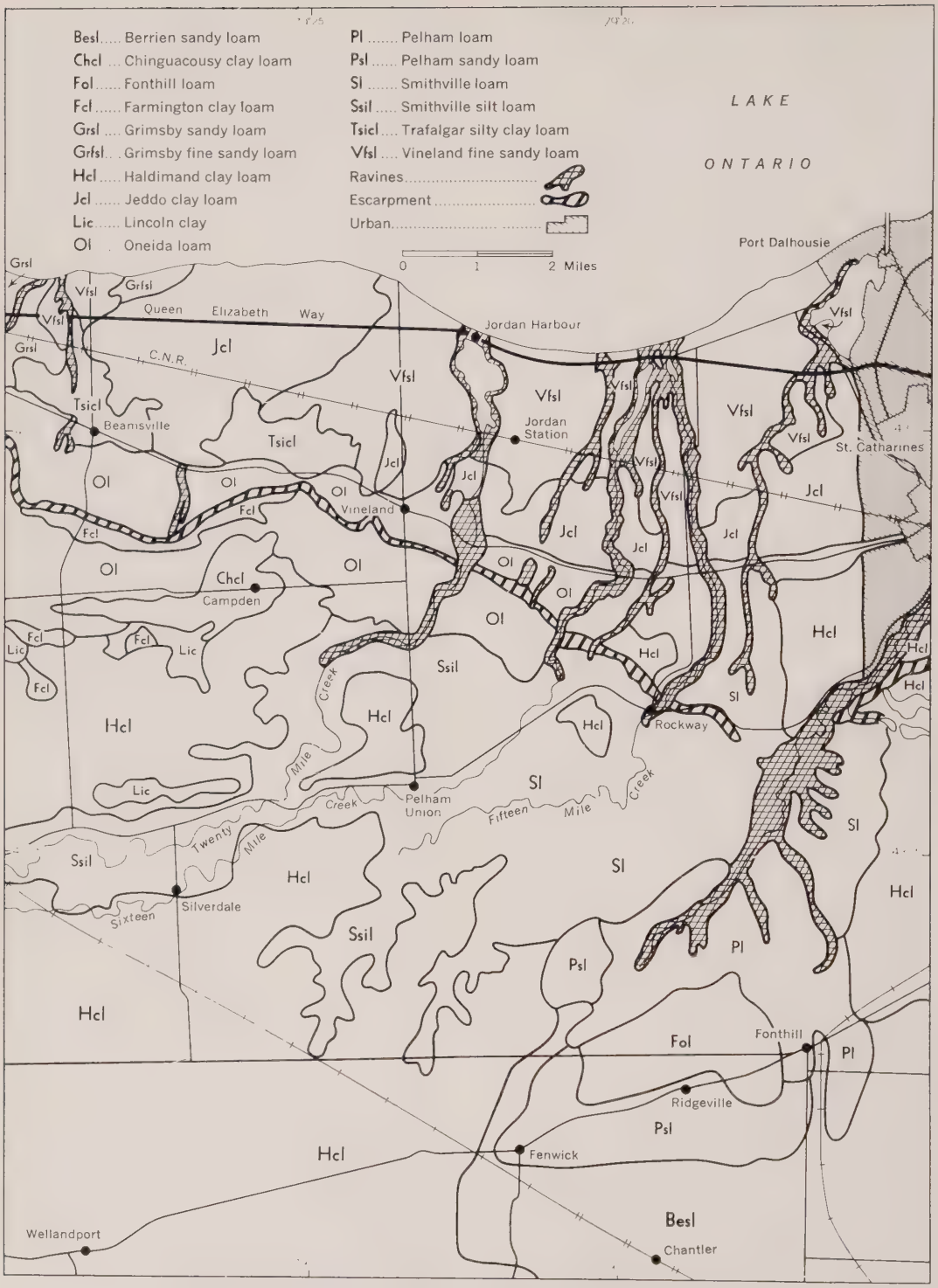


FIGURE 3. Soil types—Niagara West sheet (adapted from the Ontario Soil Survey).

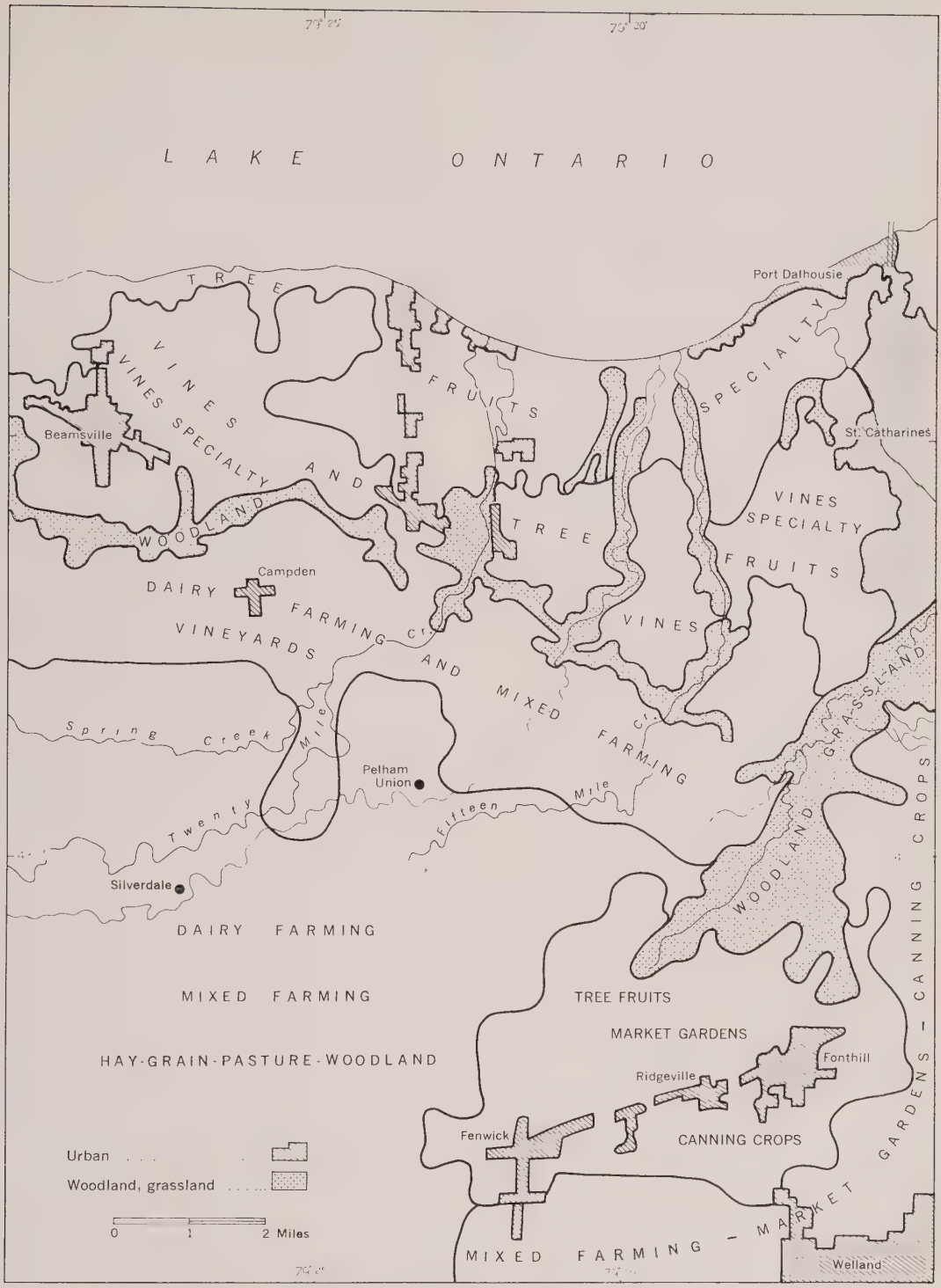


FIGURE 4. Land-use types — Niagara West sheet.

in tree fruits coincides quite closely with the Vineland fine sandy loam and the Grimsby sandy loam. These two soil types are rated good for all types of tree fruits and small fruits. The heavier textured and more poorly drained Jeddo clay loam which occupies extensive areas to the east of Beamsville and on the bench to the south of Highway 8 has 70 per cent in vines, although this type of soil is not ideally suited for grapes. Above the escarpment the vineyards are confined, for the most part, to the areas of better drainage which have soils of the Oneida and Smithville series. The Oneida loam, the Smithville loam and the Smithville silt loam have proven to be excellent soils for Concord grapes and can be expected under average management to yield five tons or more per acre.

As stated previously, the 1:50,000 maps reveal the general patterns but fail badly in important details. The great variety of tree fruits and small fruits cannot be depicted and the intricate pattern of fields associated with such crops is not evident. Small pockets of Jeddo clay loam within the Vineland or Grimsby types are generally used for pears, plums or vines while even shallow patches of sand overlying heavy till are oftentimes utilized for peaches.

The loams and sandy loams of the Fonthill region have been well utilized for tree fruits, market gardens and canning crops. At the same time, the attractive undulating landscape with its good drainage has attracted many people from Welland who prefer to reside in this type of rural setting.

The steep slopes of the Niagara escarpment and the ravines of the several creeks stand out as ribbons of green while larger patches of woodland occupy the more poorly drained depressions of the Haldimand clay plain and the less well-developed back concessions.

The relationship of type of farming to soils and relief is evident. The well-drained Oneida loams have dairy farming and vineyards. The Smithville silt loams with their pockets of Haldimand clay loam provide a suitable basis for dairy farming, mixed farming and grapes, while the flatter parts of the Haldimand clay plain are occupied by mixed farms and dairy farms. To the south of Campden, vineyards are smaller and more scattered because of less suitable soils and greater risks of frost.

The maps show in a valuable way the location and directional trends of urbanization. Fingers of residential development extend out from Beamsville and Vineland and along the roads leading from Welland to Fonthill.

In short, the Niagara West sheet fails to show adequately the detailed pattern of actual land use but does reveal gross areal differences. Within these limitations, it provides a valuable basis for understanding regional development and for the study of geographic relationships.

## ALTERNATIVE METHODS OF LAND-USE MAPPING

It would have been desirable to have produced a more simplified land-use map of the peninsula on a smaller scale employing fewer categories and showing only the broad patterns, using a system similar to that devised by McClellan (1964) for the Canada Land Inventory. In addition, a series of larger scale land-use maps of sample areas might have been produced revealing the details of land use and farm organization. These latter types provide a more suitable basis for correlation of land use with local conditions of soil, slope, drainage, economic factors and management.

A more detailed knowledge of the use capability of the soil is a basic necessity and must be ascertained before other aspects of land use are investigated. Once the best use of land from a physical capability standpoint has been decided, then social and economic factors of the rural environment may be evaluated with greater accuracy.

H. A. Wood (1962) has suggested two alternative methods to those adopted in the Niagara survey. One is to superimpose upon the land-use map a scattering of dots having precise quantitative meaning. The difficulty with this method is that with more than one overlay the map becomes cluttered and confusing to read. The second, a more flexible alternative, is to map land-use combinations. The symbols indicate the percentage of area occupied by the various components. As emphasis is on mapping the existing land-use patterns, the gross generalizations which oftentimes render a land-use map meaningless, are avoided. Pilot studies should be carried out in a variety of regions in order to develop a comprehensive system of classification based on land-use combinations. The preparation of these maps would be time-consuming but the results would be more useful.

However, even these better methods of land-use mapping would not meet the real need unless the present use inventory were part of an integrated study of land resources. The land-use maps of the Niagara Peninsula have extremely limited value not only because the survey methods were inadequate but because the mapping was not especially designed as an integral part of a comprehensive study directed toward the solution of land-use problems. Such a study was carried out by Hills in the Cochrane area of Northern Ontario. It resulted in the production of a series of maps which show accurately and in detail the natural characteristics of the land, present use, use capability, recommended use, and use-programming (Hills, 1960). These maps provide a complete land inventory and the basis for the development and implementation of alternative land-use programs.

## CONCLUSION

The Niagara land-use maps do have educational value and provide a basis for regional description and land-use regionalization. The gross patterns of land use are clearly shown. The broad relationships between physical and cultural elements are evident and the interaction of city and rural development can be deduced. The quality of the cartography is excellent although the information conveyed is below the standard achieved by some other countries. Regardless of these assets the maps, however, have had extremely limited application. Their value has been greatly reduced by the classification used, by the scale chosen, and by the variable accuracy of field observations.

This appraisal has emphasized the need to examine objectives before launching a program of land-use mapping. Pilot studies should be undertaken in various types of agricultural regions in order to experiment further with land-use categories, symbols and scale and to create a more comprehensive classification having a wider and more practical application.

The production of costly maps having relatively little value is not desirable when the greatest need is for a comprehensive land inventory that will assist materially in solving the problems that confront those who live in the Niagara peninsula. In the peninsula, agriculture is beset by many problems including frost hazards in fruit production, imperfectly drained soils, fluctuating prices for agricultural produce, competition from foreign produce, lack of capital, low net incomes per farm, inefficient part-time farmers, and urban encroachment.

These problems should be tackled by teams of researchers drawn from several disciplines including geomorphology, climatology, pedology, agricultural science, economics, and economic geography, who will work together on specific problems in particular localities.

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# ALEXANDER MACKENZIE'S EXPLORATION OF THE GRAND RIVER

*J. K. Stager**

ABSTRACT

In the summer of 1789 Alexander Mackenzie explored and mapped the "Grand River"†, later to become known as the Mackenzie. This journey marked the turning point in the struggle for the rich furs of the Northwest and foreshadowed the amalgamation in 1821 of the Hudson's Bay Company and the Northwest Company under the former's name. Thus the expedition opened up large, rich new lanes to fur trade, and made known access routes for the remaining exploration of the west.

The present paper concerns the first of Mackenzie's explorations and is an attempt to follow his day to day downstream progress and his return to Great Slave Lake, a gruelling experience during which he spent 55 days on the river—two weeks following it downstream and the remaining 31 days returning against the current. In doing so he not only extended the known land of his day by more than a thousand miles, fixed another point on the Arctic coast of North America; but also shaped the approach and successes of subsequent explorers such as Franklin, Richardson and Rae, or Simpson and Dease.

RÉSUMÉ

Au cours de l'été 1789, Alexandre Mackenzie explora et cartographia le cours du «Grand fleuve», qui devait plus tard s'appeler fleuve Mackenzie. Son voyage marqua le début d'une orientation nouvelle de la rivalité, en cours alors dans le Nord-Ouest, entre traiteurs qui exploitaient les richesses en animaux à fourrure. Il fit pressentir la fusion, en 1821, de la Compagnie de la Baie d'Hudson et la Compagnie du Nord-Ouest sous le nom de la première. Ainsi, son expédition ouvrit de nouvelles voies à un commerce lucratif des fourrures et elle révéla des routes d'accès qui permirent d'explorer les régions vierges de l'Ouest.

Dans son étude, l'auteur traite de la première des explorations de Mackenzie en essayant de décrire jour par jour sa descente du fleuve et son retour au Grand lac des Esclaves, voyage qui consista en 55 jours d'épreuves cruelles, savoir, deux semaines pour descendre le courant et trente et un jours pour le remonter. Mackenzie reculait ainsi de plus de mille milles les limites des terres connues à cette époque, et posait un autre jalon sur la côte nord-américaine de l'océan Arctique, et son travail de pionnier fraya la voie aux explorateurs subséquents, tels que Franklin, Richardson et Rae, ou Simpson et Dease, dont il explique les succès.

## INTRODUCTION

In the summer of 1789 Alexander Mackenzie explored and mapped the river that was first known as the "Grand" but was later called "MacKenzie's River" and is now the Mackenzie. This successful enterprise completed the encirclement of the fur-trading territory of the Hudson's Bay Company on behalf of a group of Montreal traders who had recently fashioned a syndicate, which they called the Northwest Company. The Bay-based company had gradually realized that its fur lands were being invaded and its charter rights violated and had begun to meet the challenge by penetrating deeper inland and intensifying its competition. Mackenzie's voyage was therefore a turning point in the struggle for the Northwest, a struggle that ended in 1821 with the unification of the two rivals under the Hudson's Bay banner. The expedition also opened a large, rich new land to the fur trade and made

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*Dr. Stager is a member of the Department of Geography, University of British Columbia, and gathered material for this paper while a member of the Geographical Branch summer staff.

†Geographical names unapproved by the Canadian Permanent Committee on Geographic Names are placed in quotation marks the first time they are mentioned.

known the access routes for the remaining exploration of the Far Northwest.

While trading on the Athabasca River, Peter Pond gathered the information later set down on his famous map and so provided the inspiration to pursue the Great Slave Lake outlet in the hope that it would lead to the Pacific. This would mean the discovery of the long-sought water route through North America. As Pond was thus poised to realize his dream, his tempestuous nature embroiled him, however, in events that took him away from the Athabasca country, to which he never returned (McKenzie, 1889, p. 18).

At this time Mackenzie was not only young but already successful. While Pond was nearly 50 (Wagner, 1955, p. 3), he was 24 or 25 (Sheppe, 1962, p. 26). This resolute youth, who was to undertake two of the most significant exploration journeys in the history of North American discovery, had been a clerk at 16 and then a trader and in his early 20's had risen to be a bourgeois, or partner, in the Northwest Company. Now, having spent the winter of 1787-88 in Pond's company, he resolved to explore the new river with or without his senior's support.

This paper concerns the first of Mackenzie's explorations and is an attempt to follow his day-by-day downriver progress and his return to Great Slave Lake. Although some variation occurs between the reasoning and routes set down herein and those presented by Mackenzie, the main conclusions agree.

Mackenzie's journal, published 12 years after he made the voyage, is less detailed in description, at least in its coverage of the northern journey, than the narratives of many other explorers. This may be explained by his subsequent business activities and the passage of time, during which he visited the British Isles, made his way to the shores of the Pacific and then divided his attention among New York, London and Montreal. It is nevertheless possible, by plotting the recorded compass directions and comparing them with modern mapping, to reconstruct his daily progress. From time to time the journal describes identifiable landmarks, and the analysis of travel times, distances and river currents adds further data for the interpretation of the report. Mackenzie's instrumental observations—those for latitude, compass direction and compass variation—can be shown to be in error. T. F. Bredin (1963), in discussing Mackenzie's crossing of Great Slave Lake, demonstrates that his recorded latitudes are consistently too far south. An attempt to relate the recorded compass directions and the true courses along the river results in a wide range of discrepancies. Along some stretches of the river the variation seems to be as much as 50 degrees west of true north. No one value for variation can be applied to correct Mackenzie's compass observations. The errors have their source either in inferior instruments or, more likely, in the explorer's unfamiliarity with surveying, which he attempted to rectify by receiving instruction in England before his explorations toward the Pacific. Mackenzie's passage through the Delta to the Arctic Ocean has also been examined by Bredin (1962) and J. R. Mackay (1963).

## THE VOYAGE OF DISCOVERY

Alexander Mackenzie and his companions made their momentous journey in three canoes. Besides the leader, the party consisted of four French Canadians, two of whom brought wives, a German lad, the Chipewyan "English Chief" who brought two wives, and two Indian hunters.

They first entered the river that now bears the explorer's name at 5.30 a.m. on Monday, June 29, 1789 (Mackenzie, 1902, p. 220). Mackenzie "found it to be the branch or passage that was the North Channel and one of the two outlets draining Great Slave Lake." Although he describes it as "not more than half a mile wide," this river is nearly 1 mile across at the entrance (Hydrog. Serv., Can., 1958, p. 32). There is no doubt that the North Channel was Mackenzie's route because he was approaching along the north side of the lake, where the main entrance to the river tapers from an over-all width of 20 miles to a passage 2 miles across (Figure 1). In the journal he does not mention the many islands and the difficult passage through this shallow, boulder-strewn channel since at the time of his traverse the water level was high from spring melt and the stiff east breeze would raise the water at the west end of the lake (Mackenzie, 1902, p. 221).

When he passed the west end of Big Island and crossed the wide part of the river known as Beaver Lake, Mackenzie felt reassured in the conviction that he had found the main outlet of Great Slave Lake. He reasoned that the channel must be much narrower at times of low water, for his soundings were between 2 and 5 fathoms. An

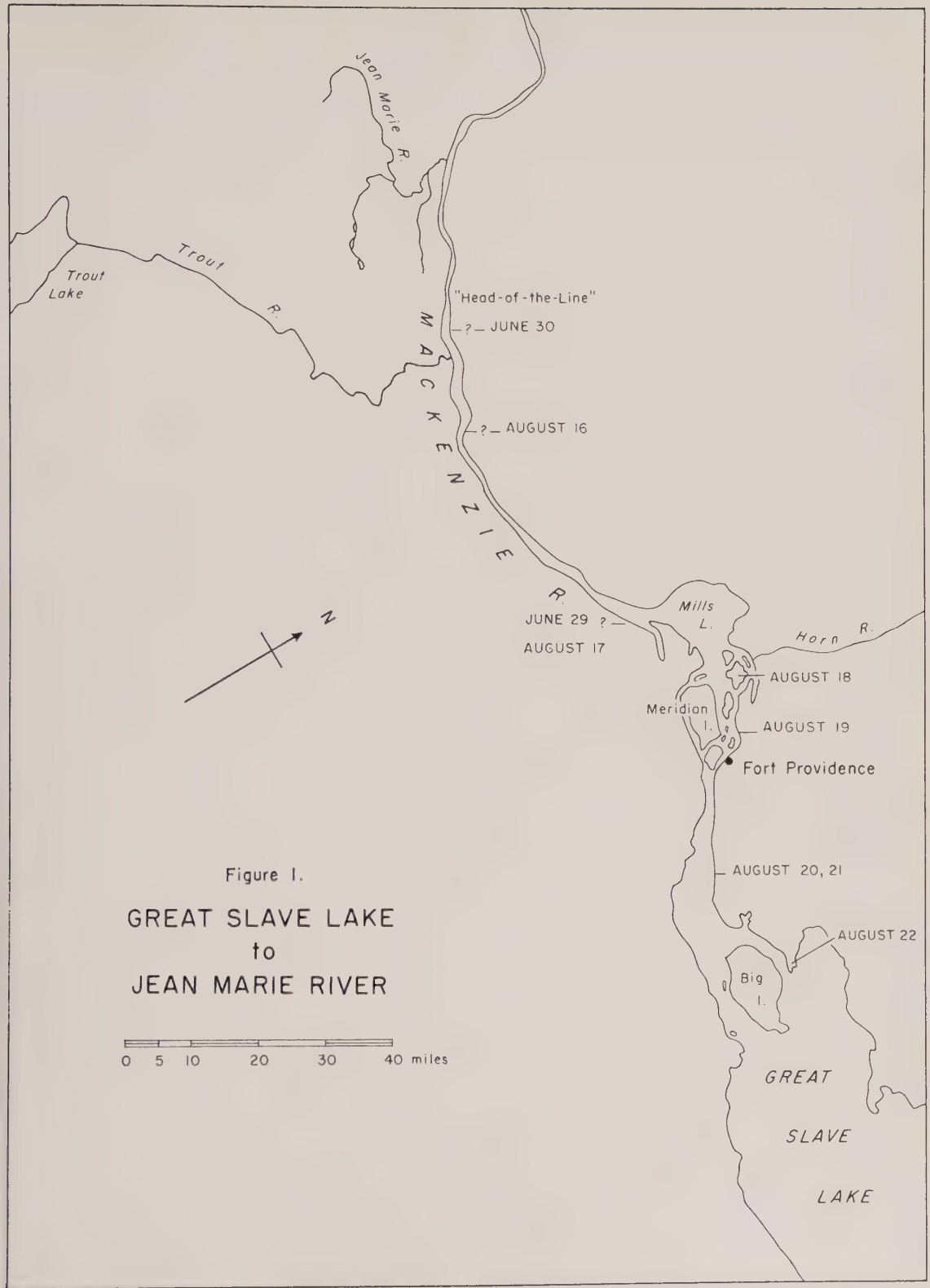


Figure 1.

GREAT SLAVE LAKE
to
JEAN MARIE RIVER

east wind combined with a strong current that probably ran at more than 3 mph (Hydrog. Serv., Can., 1958, p. 33) quickened the passage around the islands on the north side in the vicinity of what is now Fort Providence. In the southern channel around Meridian Island, the explorer observed a slower current that promised a better upstream route for his return. Where the river widens into Mills Lake the current slackened and the men resorted once again to the paddles. As the party passed the mouth of the Horn River, the Copper Indian guide from Great Slave Lake mentioned that this stream flowed from the flat-topped mountain visible to the north. Off the delta of this stream they entered Mills Lake but soon found the water too shallow for canoes and were forced to turn southwest to reach deep water and the lake outlet. The campsite selected soon after sunset is not identifiable, but it seems probable they chose the south side of the main stream as it leaves Mills Lake. There the approaches to the shore, unlike those on the north side, are not shallow or weed-covered. At this point the account indicates that the party had travelled some 63 miles since entering the river. Followed, however, with modern maps, the journal suggests that on this long day they advanced about 75 miles.

*Tuesday, June 30*—Mackenzie resumed travel at 4 a.m., and the 2 mph current below Mills Lake hastened his downstream journey. He noticed low clay and gravel banks supporting dense spruce forests in which there were many large swampy patches. Mackenzie then reports that "on the South side of the river is a ridge of low mountains, running East and West by compass. . . . We proceeded South-West by South six miles, and then came to a bay on our left, which is full of small islands, and appeared to be the entrance of a river from the South. Here the ridge of mountains terminates" (Mackenzie, 1902, pp. 222-223).

It is not easy to identify this ridge of low mountains or the stream entrance. On the basis of the 75 miles travelled between 5.30 a.m. and sunset (about 9.30 p.m.) the previous day, it seems likely that Mackenzie covered nearly 60 miles between 4 a.m. and 6 p.m., when he camped. By his own record, he estimated the distance at 57 miles. This would place the campsite a short distance above "Head-of-the-Line", a constriction of the river recorded early in the following day's account (*op. cit.*, p. 224). The "river from the South" was probably the Trout River, which rises at Trout Lake on the plateau about 60 miles southwest of the Mackenzie and has a wide mouth containing several low-lying islands. If so, the mountains Mackenzie described must be east of the Trout River and trend along an east-west line. The river banks in this stretch are low and Mackenzie noted that the day was "fine and calm" (*op. cit.*, p. 222). Visibility should therefore have been good. Yet there are no mountains, but it is possible that he could see the edge of the plateau to the south between 60 and 80 miles away. Only under the most favourable conditions is the top of this upland visible from the river. Instead it is more likely that the observed ridge was the skyline that lies nearer to the river and is caused by the gradual rise of the land from the water to a general elevation of 900 to 1,000 feet above sea level. This rise is higher on the south than on the north side, and the contrast may have led to the description of the land in terms of a low mountain ridge. The generally low banks and the width of the river, which here varies from 1 to 2 miles, combine to distort the true sense of scale and so lead to the exaggeration of hills into mountains.

It seems clear that the second day brought the explorer to a campsite a few miles beyond the Trout River (Figure 2). As many of the shallows in the channel are on the south side, it is likely that Mackenzie kept to the north and camped on the north shore, where the banks are slightly lower.

*Wednesday, July 1*—Shortly after the time of departure, 4.30 a.m., the canoes came to the already mentioned narrowing of the river later called Head-of-the-Line. Here the river becomes less than half a mile wide and the current increases to between 5 and 7 mph. Mackenzie remarks on the high banks but notes that they are not perpendicular. Throughout this confined 60-mile stretch the river is never more than a mile wide and is flanked by high gravel banks that rise as much as 60 feet above the water on the south side and from 20 to 40 feet above it on the north side. The current carried the party along swiftly between banks that restricted their view, with the result that they were able to observe few topographic features. The account, however, does mention a river "on the South-East side" (*op. cit.*, p. 224), which must be either Jean Marie River or the Spence River. The former is the more likely because its mouth is the larger

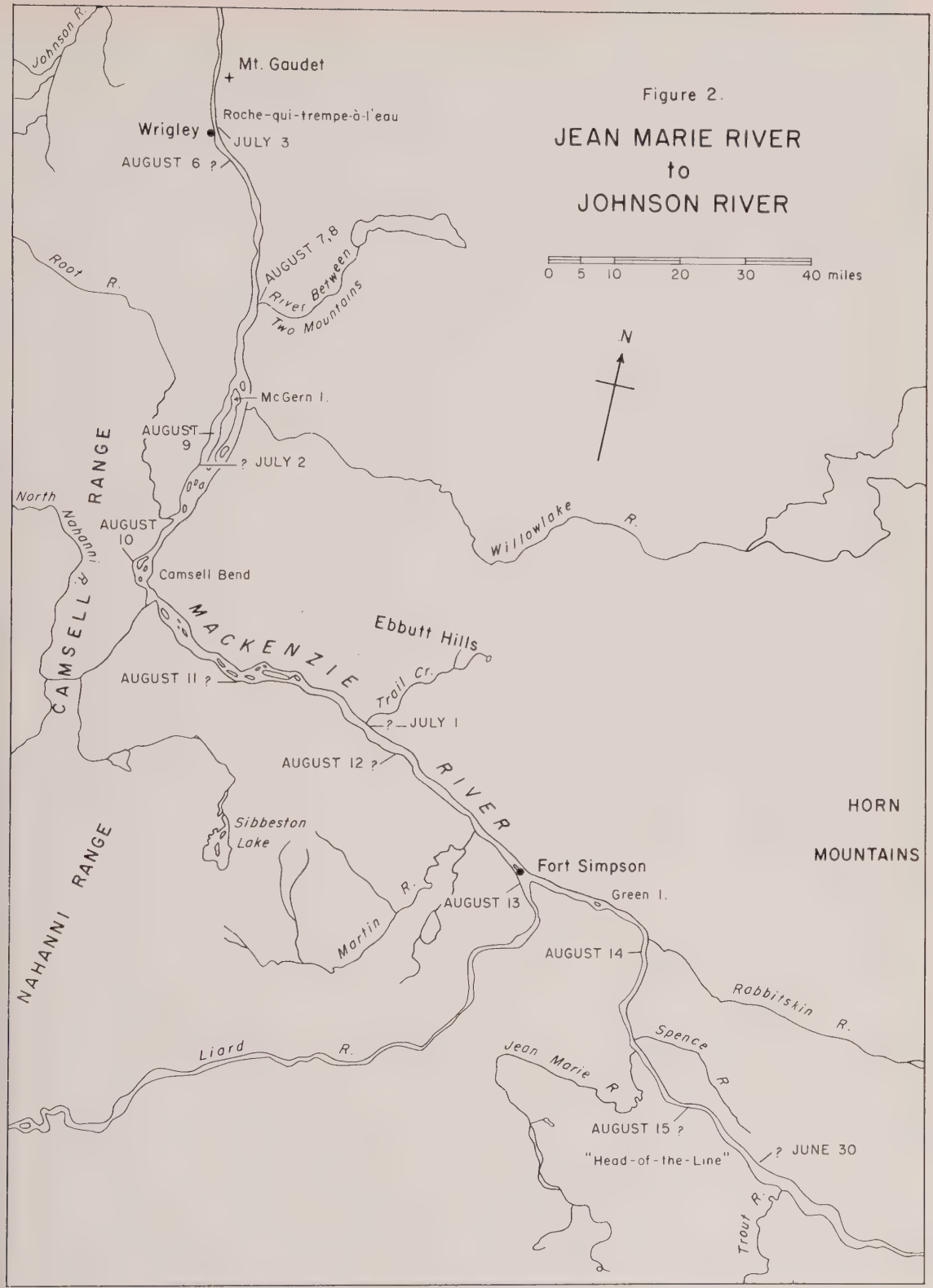
Figure 2.
JEAN MARIE RIVER
to
JOHNSON RIVER
0 5 10 20 30 40 miles
N
Johnson R.
Mt. Gaudet
Roche-qui-trempe-à-l'eau
Wrigley
JULY 3
AUGUST 6 ?
Root R.
AUGUST 7,8
River Between
Two Mountains
McGern I.
AUGUST 9
? JULY 2
CAMSELL RANGE
North Nahanni R.
AUGUST 10
Camsell Bend
Willowlake R.
MACKENZIE RIVER
Ebbutt Hills
Trail Cr.
AUGUST 11 ?
? JULY 1
AUGUST 12 ?
HORN MOUNTAINS
Sibbeston Lake
NAHANNI RANGE
Martin R.
Fort Simpson
AUGUST 13
Green I.
AUGUST 14
Rabbitskin R.
Spence R.
Liard R.
Jean Marie R.
AUGUST 15 ?
"Head-of-the-Line"
? JUNE 30
Trout R.

and is very evident during the downstream passage, even from the opposite bank. The Spence River enters the Mackenzie by a divided mouth, one part of which, when viewed from the main river, seems to flow from the southeast as indicated by the compass. This may be what Mackenzie meant.

Where the river flows almost due north, the force of the current was dramatically demonstrated when Mackenzie, trying to retrieve the lead lost from the sounding line, found that not even with the paddling of eight men reinforced by a line estimated to be as strong as four additional paddles could he make any headway against the current.

Mackenzie says that, as they continued north, he "saw a high mountain, bearing South from us" (*op. cit.*, p. 224). This is a mystery, for no mountain is visible from this part of the river. Even 5,000-foot peaks in the Liard Range, a hundred or more miles to the southwest, are hidden. The highest parts of the upland east of Sibbeston Lake and west of Fort Simpson are 2,700 feet above the sea or 2,200 feet above the point on the river from which Mackenzie was observing. Perhaps these hills could be seen clearly if atmospheric conditions permitted, but they were to the west of the explorer rather than to the south, even if compass variation is allowed for. The only remaining possibility is that the "mountain" is a continuation of the southern skyline, which rises eastward toward the plateau surrounding Trout Lake. It is hard to see why this upland should be called a mountain in comparison with the prominent Horn Mountains seen the previous day. There is, however, a well-marked ridge visible to the north; perhaps a reversal of direction occurred in the record during the long interval between observation and publication.

The continuation of the journey took Mackenzie past the mouth of a small river that entered the north side of the main stream near where the latter turns west-northwest by the compass. This was the mouth of the Rabbitskin River, which drains a number of lakes near Mills Lake and the southern flanks of Horn Mountains and enters the Mackenzie over a shallow bar composed of boulders and gravel (Hydrog. Serv., Can., 1958, p. 39). To the west the Mackenzie River is bordered by banks of increasing height, some parts of which have mud and gravel exposed while others are covered with spruce and poplar trees. Aided by the current, which runs as fast as 6 mph, the party must have moved along easily and quickly. Boulder-covered shallows jutting into the main stream from both sides restrict the width of the deep-water channel to 200 yards. Great, turbulent eddies at Green Island Rapids, between Green Island and Hanson Island, heighten the impression of swift passage. Mackenzie "landed upon a small island, where there were the poles of four lodges standing, which we concluded to have belonged to the Knisteneaux, on their war excursions, six or seven years ago. This course was . . . to where the river of the Mountain falls in from the Southward" (Mackenzie, 1902, p. 225). It is likely that what was described was Martin Island, which is high and non-alluvial and lies in the Mackenzie east of its confluence with the Liard, or "River of the Mountain". From this island, the joining of the two rivers can be observed. Mackenzie probably passed along the north shore, since he did not climb the 50-foot cutbank of the island on which Fort Simpson is located, from which he could have had an impressive view of the mouth of the largest tributary to enter his river. Instead he describes the scene simply by saying that "it appears to be a very large river, whose mouth is half a mile broad" (*loc. cit.*). Nor was there mention of the striking phenomenon distinguishable for some 150 miles downstream, of the flow of the clean, clear Mackenzie water alongside that of the Liard, which is charged with sediment. Six miles beyond the junction, according to the journal, a small river was observed entering from the south side. This is the Martin River, which joins the Mackenzie 10 miles downstream. Mackenzie's erroneous estimate of the distance is due to the quickening of the current to about 4 mph below the mouth of the Liard (Hydrog. Serv., Can., 1958, p. 43).

By Mackenzie's reckoning, the evening camp was about 24 miles from the Liard River, where he "landed opposite to an island, the mountains to the Southward being in sight" (Mackenzie, 1902, p. 225). On this island they cached some pemmican to relieve the heavily laden boats and provide for their return.

It has already been noted that Mackenzie's estimates of distance were often wrong and usually short. Accordingly, his cache island is more than 24 miles downstream and is probably one of the two islands near Trail Creek. It is possible, too, that he landed on the north bank of the river where the low gravel and sand shore makes

a better approach than the high south bank. The day's travel, by the explorer's own account, was some 66 miles, but the real distance was probably 100 miles. If the average speed of the current was 5 mph, which it might well have been in view of the 7 mph reached in the narrows below Head-of-the-Line, this stretch might have been covered in 20 hours by drifting alone. If, in addition, Mackenzie's crew paddled 3 mph, the whole day's passage could have been made, without stopping, in $12\frac{1}{2}$ hours.

*Thursday, July 2.*—It was foggy at 5.30 a.m., when the group left their encampment. By 7 o'clock the fog had cleared, and dark, muddy water was disclosed instead of the clear stream previously travelled. Since the waters of the clear Mackenzie and the muddy Liard keep separate for more than 150 miles downstream from their junction, it is evident that Mackenzie had crossed in the fog to the southwest side. The muddy water "must have proceeded from the influx of some river to the Southward, but where these streams first blended their waters, the fog prevented us from observing" (*op. cit.*, p. 226). Having followed the north bank of his river and having been unable, from the low angle of observation afforded by his canoe, to see the change of colour as he passed the mouth of the tributary, he did not realize that the Liard, or River of the Mountain, was the cause of the change.

Where Mackenzie found himself on the morning of July 2, the speed of the current reaches 6 mph. Through this stretch with the aid of paddles the party travelled some 20 miles before 9 o'clock. "At nine we perceived a very high mountain ahead, which appeared, on our nearer approach, to be rather a cluster of mountains, stretching as far as our view could reach to the Southward, and whose tops were lost in the clouds" (*loc. cit.*). This was the first glimpse Mackenzie had of the Franklin Mountains, which are the eastern ramparts of the northern cordillera. What he observed was, without doubt, the south end of the Camsell Range, which comes into view 230 miles from Great Slave Lake. The peaks of the Nahanni Range to the south, which are around 4,000 feet in height, become visible about 10 miles farther on. These must have been the cluster mentioned in the narrative. With their summits partly shrouded in cloud, the mountains might not have been recognized until the party was within 25 miles, although on a clear day they can be seen for more than 40 miles. At this point Mackenzie was probably travelling on the south side of several large islands and next to the banks which, decreasing in height downstream from his previous encampment, become low and expose the rolling country southward for a better view of the land beyond.

Approaching the mountain front in a thunderstorm, they saw the slopes covered with forest above which jutted barren peaks. White patches, at first presumed to be a curious type of rock, later proved to be only snow. Nearing the mountains, Mackenzie proceeded with caution, expecting to meet waterfalls or rapids. The increasing number of islands and the mountains themselves may have contributed to an uneasy feeling that the river was about to cascade over or through some topographic barrier. "This was such a prevalent idea, that all of us were occasionally persuaded that we heard those sounds which betokened a fall of water" (*op. cit.*, p. 227).

The change of the river course from west by north "to north by west along the mountains" (*loc. cit.*) indicates the rounding of Camsell Bend. Mackenzie, however, did not record the North Nahanni River, which joins the main river a few miles upstream from the Bend, its mouth opening around several small islands and being plainly visible. Although the tributary valley can be seen from a point downstream, the apparent overlapping of the Nahanni Mountains and the south end of the Camsell Range may have obscured it. The passage beyond Camsell Bend leads among many islands, and these prevented Mackenzie from noticing another mountain tributary, the Root River, which enters from the west. The land along both banks is low but the mountains to the west dominate in that direction. To the east, the rolling, hilly surface gradually becomes a ridge and increases in height toward the north.

By Mackenzie's estimation, the party travelled 21 miles from Camsell Bend before landing for the night at 8 o'clock on the east or right bank. There is no other evidence concerning this encampment, and it is difficult to determine exactly what part of the river was reached. If he had kept to the right side of the stream he would have passed east of McGern Island, which is more than 14 miles long and 100 feet high and divides the Mackenzie into two channels. Whatever the course, the camp should have been on or across from this island. It probably lay near the south end of the island and more than 21 miles from Camsell Bend. The distance estimated in the

account of the day's travel is 63 miles, but it was probably between 70 and 80. The decrease in the disparity between the journal distance and the true distance is consistent with the slower current, which averages 3 mph through this island-studded stretch (Hydrog. Serv., Can., 1958, p. 43).

*Friday, July 3*—The night rain having sufficiently subsided, the party broke camp about 7 a.m. The river course followed in the early morning is described as "being enclosed by high mountains on either side" (Mackenzie, 1902, p. 227). Back from the west bank lies the Camsell Range; on the east bank, north of the Willowlake River, the land gradually rises and becomes distinctly mountainous, thus forming the southern end of the McConnell Range of the Franklin Mountains. In the journal there is no mention of the Willowlake River, which enters from the east and is 300 yards wide at the mouth and which Mackenzie would most certainly have seen in passing east of McGern Island. Perhaps he missed it by taking the left fork, along the west side. Another factor was the weather: "a strong headwind, and the rain was so violent as to compel us to land at ten o'clock" (*loc. cit.*). The rain and wind may have so reduced visibility as to make the river mouth unobservable, or the attention and work required to fight forward against the elements may have left little time for observation.

On continuing the journey after the storm Mackenzie soon found that "a river fell in from the North, and in a short time the current became strong and rapid, running with great rapidity among rocky islands, which were the first that we had seen in this river" (*op. cit.*, p. 228). In a further description of the river he reports that "the current has been so strong, that it was at length, in an actual ebullition, and produced an hissing noise like a kettle of water in a moderate state of boiling" (*op. cit.*, p. 229). A few miles downstream from the place where the River Between Two Mountains joins the Mackenzie from the east, the main course narrows, being confined between banks that rise as high as 400 feet and then decrease downstream to 100 feet. The banks, steep and wooded all the way, restrict the river and so increase its speed to give the seething effect reported in the journal. This stretch is now known as "Little Rapids". Along the route Mackenzie passed several native encampments but saw no one and concluded that the camps were not recent. He "encamped at eight in the evening, at the foot of a high hill, on the North shore, which in some parts rose perpendicular from the river. I immediately ascended it . . . and in about an hour and a half, with very hard walking . . . gained the summit . . . . The prospect from this height was not so extensive as we expected, as it was terminated by a circular range of hills, of the same elevation as that on which we stood. The intervals between the hills were covered with small lakes . . ." (*op. cit.*, p. 228). This campsite was undoubtedly at the foot of Roche-qui-trempe-à-l'eau. The rock face rises 1,200 feet sheer from the waterside and can be climbed only by moving up the flank. The view eastward from the top terminates at the line of peaks of the main part of the McConnell Range of the Franklin Mountains. Although they are higher than the peak upon which Mackenzie stood, their distance from the river, about 12 miles or more, may have created the impression of a similar height and would most certainly have prevented observation beyond them. The intervening land is dotted with many lakes (M. Y. Williams: personal communication).

The explorer was surpprised to find that this high area had an Indian encampment. His native companions explained that the local people were in the habit of using such a situation as a defence against marauding Cree from the south, who, now in possession of firearms, were extending their hunting grounds to satisfy trading needs.

Mackenzie claimed 45 miles as the length of the day's journey, but the distance actually covered seems to have been about 52 miles.

*Saturday, July 4*—Wind and rain continued on this day but did not prevent the resumption of the journey. The passage lay mostly between rather steep banks from 150 to 300 feet high that were wooded on all but the bare slopes that had become exposed through undercutting. Below Wrigley or Roche-qui-trempe-à-l'eau the river averages about 4 mph, and its course throughout is relatively straight and seldom more than a mile wide. The hurried travel over this section is reflected in the sparsity of the observations recorded for the day. Mackenzie noted the confluence of his river with the Blackwater, which drains westward through the mountains from the lake of the same name beyond the mountain front. He mentions the entrance to the Dahadinni River, which flows from the edge of the Mackenzie Mountains in the west. Farther north, some 445

miles from Great Slave Lake, the Redstone River from the west and the Saline River from the east empty into the Mackenzie opposite each other. Here Mackenzie viewed "a mountain ahead, fifteen miles" (Mackenzie, 1902, p. 229). This was probably Mount Clark (4,798 feet), which is the only prominent feature in the vicinity and lies in the McConnell Range about 15 miles east of the river, from which Mackenzie observed it. Below the Blackwater River the Mackenzie seems deep and strong, once again seething as it drives downstream between 6 and 8 mph. The party camped at 8 p.m. on an island, possibly the first or second very large island 10 miles or more beyond the mouth of the Keele River (Figure 3). The day's journey was long, even by Mackenzie's standards. He gives the distance as 70 miles, but measured on the map, it was probably 105 miles. Once again the discrepancy between the estimate and the actuality is great and awkward to explain, especially in view of the closer agreement shown on other days. In his estimates Mackenzie may have been deceived by the variability of the current he encountered that day.

*Sunday, July 5*—The sun had been below the horizon exactly four hours when, at 1.53 a.m., it rose and Mackenzie's party was able to continue. The river leads between low clay banks on the west and steep, scarped banks rising to 300 feet on the east. They passed Old Fort Point, where a trading post was later erected. A few miles beyond, the river widens and the current slackens to 3 or 4 mph. The journal reports that here Mackenzie could see "a ridge of high mountains before us, covered with snow" (*op. cit.*, p. 230). It is hard to know precisely what mountains were observed, for mountains were visible in all directions.

In the next day's entries Mackenzie refers once again to "the ridge of snowy mountains always in sight" (*op. cit.*, p. 240). If this is the ridge seen the previous day, what was initially observed was possibly the edge of the Mackenzie Mountains, away to the west. These mountains, with peaks rising about 5,000 feet, form the western horizon and appear as a snowy ridge visible for many miles of the journey downstream.

The remainder of the day's travel took Mackenzie past the mouth of the Great Bear River, which he noted to be deep and about 100 yards wide. He observed and recorded that the water, unlike the Mackenzie's flow, which was now muddy, was of a clear sea green. That night, strong wind and rain forced the party to land and camp beyond Bear Rock (1,488 feet above sea level), probably on the north bank. Franklin, who came later, described this feature, which rises abruptly from the water and leads on to the southern end of the Norman Range, in the Franklin Mountains. The local Indians believed that a storm raged continually on the summit.

The distance travelled that day was estimated to be only about 25 miles, but it probably amounted, in reality, to nearly 50. The reason for this comparative lack of progress was that the party made their first contact with the Mackenzie valley inhabitants. When he was somewhere upstream from the Great Bear River on the north shore, Mackenzie "saw several smokes" and "made every exertion to approach" (*op. cit.*, p. 230). The natives were taken by surprise and could escape neither into the woods nor by canoe. Mackenzie's party kept a discreet distance, pitched their tents and, by means of the Chipewyan language, gave assurance of peaceful intentions. Terror and confusion shortly gave way to calm, and it was apparent that the language of the English Chief, who came from the far-off Athabasca region, was understood even at this distance from his home. The Indians, about 25 to 30 in number, were of the Slave and Dogrib tribes. "We made them smoke, though it was evident they did not know the use of tobacco; we likewise supplied them with grog; but I am disposed to think, that they accepted our civilities rather from fear than inclination" (*op. cit.*, p. 231). Better received were gifts of "knives, beads, awls, rings, gartering, fire-steels, flints and hatchets; so that they became more familiar even than we expected, for we could not keep them out of our tents" (*loc. cit.*, and p. 232).

Through his interpreter Mackenzie sought information about the country and especially about what lay beyond in the voyage to the sea. What the Indians told him was mostly pure fabrication – the great distances to the sea, fabulous monsters of unlimited power, and some half truths about two falls in the river. Mackenzie discounted these stories, but they impressed his own Indians, who were weary of the journey's hard pace and easily susceptible to discouragement. They became frightened, and the leader had considerable trouble in convincing them of their folly.

Mackenzie spent more than eight hours with these natives and recorded facts about their clothing, shelter, implements and personal adorn-



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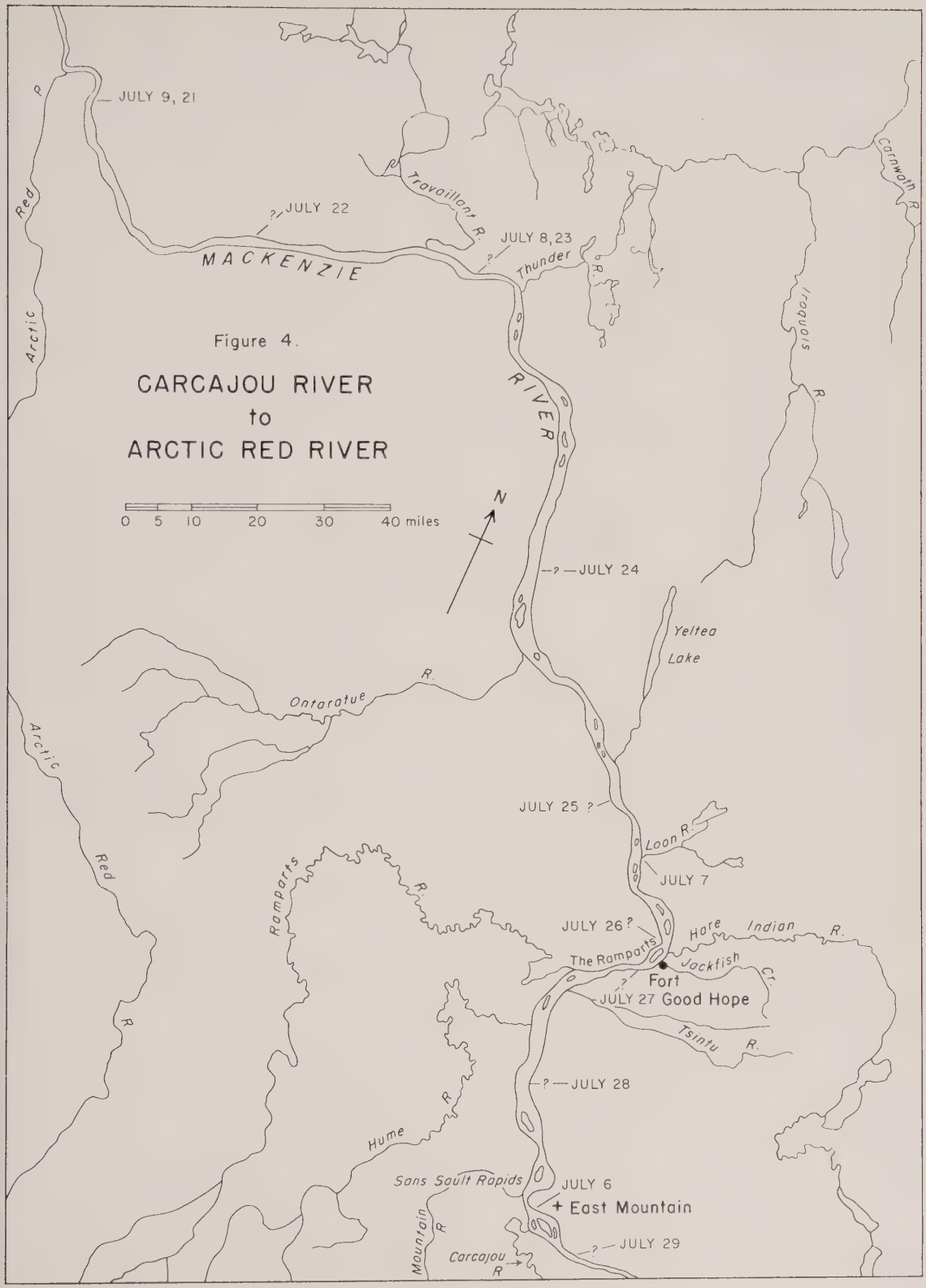
Figure 3.
JOHNSON RIVER
to
CARCAJOU RIVER
0 5 10 20 30 40 miles
N
Carcajou R.
JULY 30
NORMAN
MACKENZIE
RANGE
Norman Wells
?— JULY 31
Bear Rock
JULY 5,
AUGUST 1
Fort
Norman
Great
Bear
R.
MACKAY
RANGE
R.
?— AUGUST 2
Great
Bear
Lake
Old Fort Point
Keele
R.
JULY 4
?— AUGUST 3
+ Mt. Clark
Saline
R.
R.
Redstone
R.
Dahadinni
R.
AUGUST 4 —?
Mc CONNELL
RANGE
Blackwater
R.
R
Johnson
?— AUGUST 5


JULY 9, 21
Red R.
Arctic
?JULY 22
MACKENZIE
Travaillant R.
JULY 8, 23
Thunder R.
Cornwall R.
Iroquois R.
RIVER
Figure 4.
CARCAJOU RIVER
to
ARCTIC RED RIVER
0 5 10 20 30 40 miles
N
—?—JULY 24
Yeltea Lake
Ontaratue R.
Arctic Red R.
JULY 25 ?
Loon R.
JULY 7
Ramparts R.
JULY 26?
Hare Indian R.
The Ramparts
Jackfish Cr.
Fort
?
JULY 27 Good Hope
Tsintu R.
?—JULY 28
Hume R.
Sans Sault Rapids
JULY 6
+ East Mountain
Mountain R.
Carcajou R.
?—JULY 29



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ments. He learned also about their canoes and something of their relations with neighbouring tribes. In an exchange of gifts made upon departure, the group obtained one of the Indians to act as guide. He was, in fact, virtually forced to accompany the party, and Mackenzie had to keep a close watch on him to prevent his escape.

*Monday, July 6*—The party left Bear Rock at 3 a.m. in raw, cloudy weather. They encamped again at half past seven by the south edge of East Mountain about 110 miles downstream, having averaged $6\frac{2}{3}$ mph for the day (Figure 4). These are remarkable distances, but the current was a great help. Through this part of the river, it runs up to 4 mph, so that $16\frac{1}{2}$ hours' drifting would alone have carried them 65 miles. Thus the day's paddling amounted virtually to only 40 miles at less than 3 mph. Mackenzie's estimated distance was 79 miles.

From the present site of Fort Norman to East Mountain the river is never less than a mile across, and it frequently widens to 3 and sometimes 4 miles where it divides around islands. Mackenzie noted that they passed many islands and nearly all were flanked to some extent by shoals. The height of the banks on either side is in places as much as 150 feet but is mainly between 20 and 40 feet. East of the river timbered land rises steadily to the Norman Range. On the west side, farther away, is the solid front of the Mackenzie Mountains. These mountains, the native guide explained to Mackenzie, were the home of "great numbers of bears and small white buffaloes . . ." and were "also inhabited by Indians" (*op. cit.*, pp. 240-241). The language difficulty or inadequacies in the informant's descriptive power are presumed to have prevented a closer identification of the "small white buffaloes" with either the mountain goats or the sheep that live in the region.

When they camped beneath East Mountain, Mackenzie made an effort to climb it but was "almost suffocated by clouds of mosquitoes" (*loc. cit.*) and forced to give up. He could see, however, the Mountain River flowing from the west and joining the main stream a short way down from camp. In the course below the mountain on which he stood, Mackenzie also saw a rippling current, which is now known as Sans Sault Rapids. This he had to pass through the next day.

*Tuesday, July 7*—At 4 a.m. the party crossed to the west side of the river to avoid the rapids seen the night before. In so doing, they found that there had been no real need to make this detour, and Mackenzie began to doubt the existence of the dangers along the river reported by the natives some days previously. The travellers passed downstream between banks 100 feet or more in height and were guided through the rapids above The Ramparts by Indians encamped by the Tsintu River. Soon The Ramparts themselves came into view, and the group stopped to examine the narrowing of the river where it becomes confined between these perpendicular cliffs of limestone—"white rock" as the explorer called it— that rise more than 200 feet above the water level. This part of the river flows quickly, its speed varying from 5 mph at Sans Sault Rapids to 4 mph along the island-dotted run to the rapids above The Ramparts, which cause the flow to increase to 6 mph.

When the river enters The Ramparts proper, the water flows deep and more quietly. The group followed some Indians through and noted that the current had not increased but had, rather, decreased to about 3 mph. There, where the river is not more than a quarter of a mile wide, Mackenzie found 50 fathoms of water when sounding. Beyond this point, the natives informed him, he would encounter no more obstructions. As the party advanced, they saw Jackfish Creek and the wider mouth of the Hare Indian River. According to the journal they continued an additional 9 miles following a course that ran west and then northwest. That night their camp probably lay near the mouth of the Loon River, possibly on the west shore. It must have been hard to find a landing place, because the river banks are steep and are between 100 and 200 feet high. A few small streams from the west, however, have cut valleys down to river level, leaving enough low ground for a small encampment.

The day's distance recorded in the journal is 36 miles, but for some stretches no distances were set down. The party probably travelled about 55 miles, which was not far for the 16-hour day they had put in.

The low daily mileage was occasioned by frequent encounters with encamped natives. The first camp, occupied by about 18 persons, was by the Tsintu River. Another, with 36, lay below The Ramparts, probably at the mouth of Jackfish Creek. The latter location, which is now the site of Fort Good Hope, is noted for its fishery. Mackenzie recorded that its occupants had plenty

of high-quality fish to share. Some of them followed him downstream to the Hare Indian River, where a group of 22 Indians supplied him with fresh rabbit and partridge meat. A few miles farther on, the explorers stopped again to receive more gifts of rabbit meat from another small encampment. In addition to the time taken in landing, formalities and departures, these visits caused delay as Mackenzie tried to learn what he could about the country. On each occasion the natives' turmoil at seeing white people for the first time had to be calmed with gifts. These consisted of metal instruments and decorations. The rites, which usually aroused the curiosity of the natives, were followed by entertainment and feasting. Because of these delays, it was impossible to cover long distances.

*Wednesday, July 8*—The short distance travelled on the previous day may well have prompted Mackenzie to get an earlier start, for he resumed his journey at 2.30 a.m. Nevertheless, the apparently heavy concentration of population in the lower reaches of the river still commanded his attention, and he stopped only a short way from his camp to distribute gifts to nine Indians. He did so, however, without leaving the canoes. Soon he encountered another group encamped on the north shore "beneath a hill" (*op. cit.*, p. 245). As a hill or, more properly, an upland lies along the north side of the Mackenzie for some 25 miles below the Tieda River, it is not possible to find exactly where these 25 Indians camped. Most of the inhabitants met farther up had been found near the junction of the main river and another stream, and it is probable that this latest group occupied a similar site, perhaps even on the Tieda itself, which drains Yeltea Lake, a large body of water on the upland. Here, in any case, Mackenzie learned that the natives called themselves the Hare Indians and that they were probably part of the tribe that had provided the expedition with rabbit meat on the previous day. The explorer took this opportunity to change guides. As the first guide was either a Slave or a Dogrib from the Great Bear River, it was becoming more difficult, the farther he got from his home, to prevent his escape. For this reason and also because an indigenous guide would know the new area better, Mackenzie virtually compelled one of the Hare Indians to accompany him downstream.

Farther on, on the east bank, the party met eight more Indians. These described Manitou Island, in the river, as having behind it a spirit that swallowed every person who approached. Manitou might have been any one of the many islands that choke the wide main channel of the Mackenzie below the Ontaratue River. Here the main river flows between gently sloping banks in a broad plain some 15 to 20 miles wide and covered with hundreds of lakes. In part the stretch is known as The Grand View, for it gives an unimpeded westward vista toward the Mackenzie Mountains. This grand view was not open to Mackenzie on the downstream journey because, as the journal reports, "a fog prevailed the greater part of the day, with frequent showers of small rain" (*op. cit.*, p. 247).

For the $17\frac{1}{2}$ hours of travel Mackenzie estimated his distance to be 66 miles. Measured on a map, the distance is 100 miles.

*Thursday, July 9*—During the night the unwilling guide deserted, but Mackenzie forced another to take his place. The new guide was one of a group of natives following the canoes of the explorers, who, at least according to the journal, had not camped in the presence of Indians. To prevent pursuit of the captive Mackenzie removed the paddles from nearby Indian canoes.

The day's travel began at 3.30 a.m. after a night thunderstorm, and the course was generally westward along a part of the river plagued by shifting sand bars and channel constrictions. The stream, whose width is rarely less than a mile and is usually $1\frac{1}{2}$ miles, flows between banks 100 feet to 200 feet high composed of clay with occasional outcroppings of shale, limestone and sandstone. At the time of Mackenzie's passage, as now, the constant attack of the river would have exposed bare soil in the form of cutbanks. Some stretches were nevertheless wooded with spruce, willow, poplar and pine that extended down to the water. At 8 o'clock that night the group camped on the east side of the river just above the Lower Ramparts, near the Arctic Red River. The distance for the day, as estimated by Mackenzie, was 53 miles; on the map it is 70 miles.

In the course of the day the party encountered more natives stationed along the river, but these belonged to another band or tribe whose name is given as *Deguthee Dinees*, or the Quarrellers (*op. cit.*, p. 254). They are known today as the Loucheux Indians. The explorer first met 15 of them a short distance from the day's starting point, possibly on the banks of the Mackenzie

at the mouth of the Travaillant River. The Hare Indian guide painted a dark picture of the new people, indicating that they should be avoided. Later Mackenzie heard the Loucheux speak derisively of the Hare Indians, intimating that they, the Loucheux, regarded themselves as superior. There was no language barrier between them and the Hare Indian guide, and even the English Chief could understand their speech although he himself was not understood (*op. cit.*, p. 249). Mackenzie clearly believed these natives to be more self-respecting and independent than those previously encountered.

After the usual distribution of gifts, he persuaded one to accompany him as a guide for the unknown downstream passage. This Indian said they were 10 to 11 days from the sea and that in about three nights they should meet the Eskimos. Later in the day Mackenzie found a band of about 40, who were fascinated by his blue beads. As he recorded it, they told him that "from the place where I this morning met the first of their tribe, the distance overland, on the East side, to the sea, was not long, and that from hence, by proceeding to the Westward, it was still shorter. They also represented the land on both sides as projecting to a point" (*op. cit.*, p. 255). The meaning of this is hard to unravel. Presumably the western route described was the one Mackenzie followed—that is, the Mackenzie River. The eastern route, which is more difficult, presents two possibilities. A journey up the Travaillant River to Travaillant Lake with a portage over the height of land to the upper reaches of the Kugaluk River would lead to the sea via Liverpool Bay. It is not known whether this passage is easy or whether the river is reliable for canoe travel. Perhaps a more likely link with the sea would be the Thunder River, which empties into the Mackenzie a few miles upstream from the site of the Loucheux encampment after draining one of a series of long lakes that occupy the floor of an old meltwater channel. A low saddle or portage divides these lakes from a second chain, which leads eastward to a tributary of the Iroquois River. The Iroquois, in turn, flows into the Carnwath River, whose waters empty into the Anderson River, which carries them to Liverpool Bay on the coast. Although its river links, particularly near the headwaters, are very serpentine, this route remains plausible because the lakes provide a regulated and reliable flow throughout the travelling season. It seems that only one portage is necessary for this journey.

*Friday, July 10*—Soon after his 4 a.m. departure Mackenzie noted that "the river, which here becomes narrower, flows between high rocks" (*op. cit.*, p. 256). This refers to the Lower Ramparts, a stretch of water about 8 miles long above the mouth of the Arctic Red River. There the Mackenzie is one half to three quarters of a mile wide and flows at 4¼ mph between shale banks up to 300 feet in height. Below this section the height of the banks progressively decreases and once again the view opens out. Mackenzie noted this and also remarked on the general absence of the mountainous country that he had seen almost daily throughout the journey. Beyond the Lower Ramparts, however, he observed the snow-capped Richardson Mountains, which he estimated to be about 10 miles away. Their actual distance was at least 35 miles.

In describing the country farther downstream, Mackenzie says that "here the river widens, and runs through various channels, formed by islands, some of which are without trees, and little more than banks of mud and sand; while others are covered with a kind of spruce fir, and trees of a larger size than we had seen for the last ten days. Their banks, which are about six feet above the surface of the water, display a face of solid ice, intermixed with veins of black earth, and as the heat of the sun melts the ice, the trees frequently fall into the river" (*op. cit.*, pp. 256–257).

There can be no doubt that this description refers to Point Separation, or the place where the Mackenzie River divides to begin the distributary pattern of its delta (Figure 5). The various channels, the exposure of ground ice, the collapsing banks and the bare and forested islands are all part of the characteristic delta scenery. The multiplicity of channels to the sea posed the problem of choosing a route. The Indian guide preferred the East Channel, mainly because he felt it would bypass the hated and feared Eskimos. Mackenzie, however, determining the principle by which he proposed to navigate the Delta, decided always to follow the largest stream. Thus he chose the Middle Channel, which led due north. Besides, he was curious about the Eskimos. If it proved necessary to take a more easterly route, there would always be a later opportunity.

With the mountains of the west still in view, Mackenzie observed his latitude for the first time since he entered the river. He found it to be

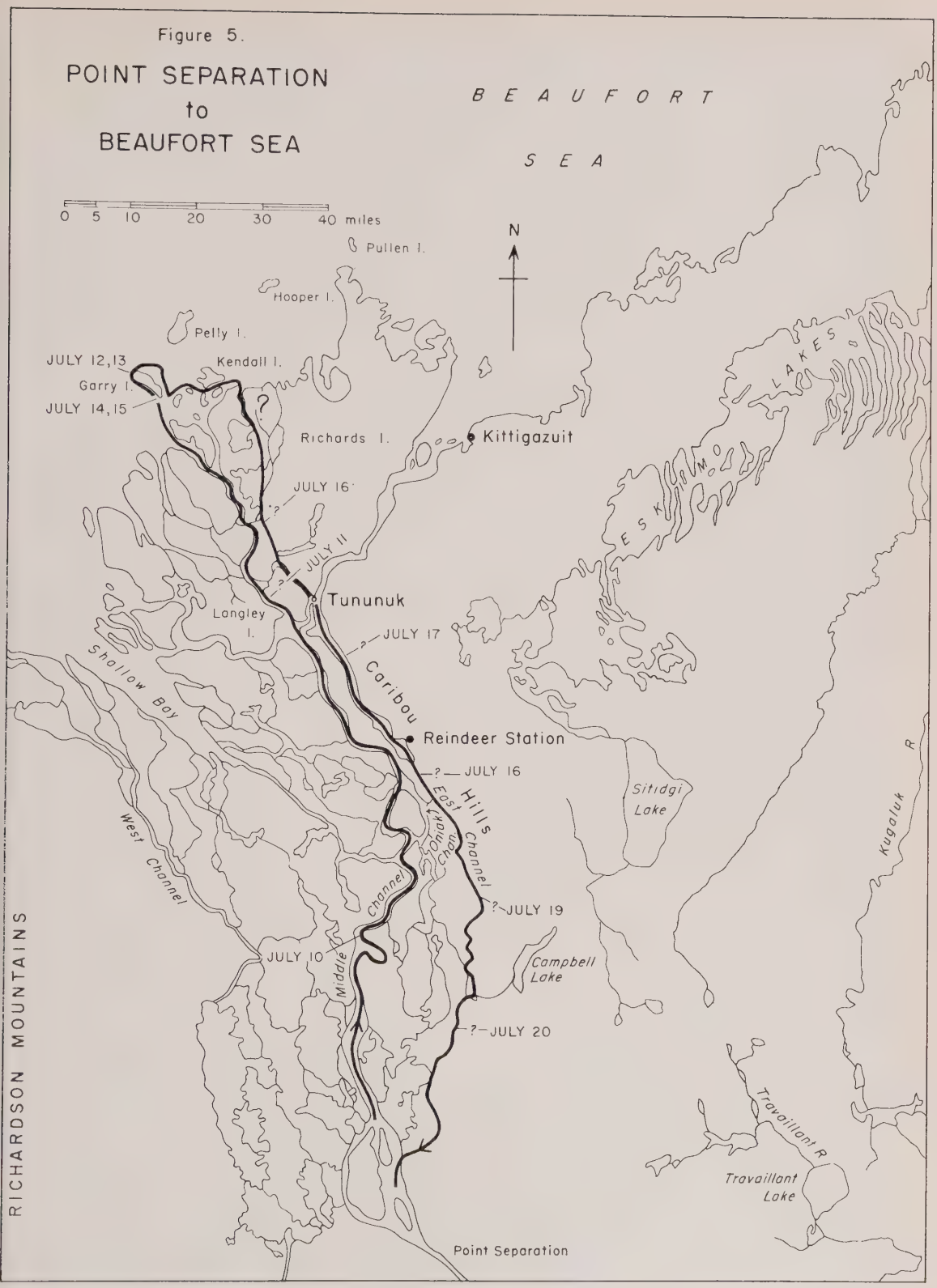
Figure 5.
POINT SEPARATION
to
BEAUFORT SEA
BEAUFORT SEA
0 5 10 20 30 40 miles
N
Pullen I.
Hooper I.
Pelly I.
Kendall I.
JULY 12,13
Garry I.
JULY 14,15
Richards I.
Kittigazuit
JULY 16
JULY 11
Tununuk
Langley I.
JULY 17
Caribou
Reindeer Station
JULY 16
Shallow Bay
West Channel
Middle Channel
East Channel
Hills Channel
JULY 19
JULY 10
Campbell Lake
JULY 20
Sitidgi Lake
Kugaluk R
Travaillant R
Travaillant Lake
Point Separation
RICHARDSON MOUNTAINS
ESKIMO LAKES

67°47′N, which is just north of where the East Channel swings out of the Middle Channel and away to the east. According to the sequence of the journal description, however, the latitude observation follows certain compass-course directions that seem, when plotted, to indicate that the foregoing observation was taken actually about latitude 67°55′N and that the reading was thus too far south. Clearly this northern latitude surprised Mackenzie, for his reckonings placed him farther south. Yet he recognized that he might have underestimated the eastward variation of the compass. In any case, his new latitude forced him to the conclusion that the long river drained into the Hyperborean (Arctic) Sea instead of the western ocean.

Mackenzie's determination to complete his exploration in spite of the depletion of his provisions, which could have been a critical handicap on the return trip to Athabasca, aroused considerable opposition. The guide had not been to *Benahullo Toe* "(White Man's Lake)", as the ocean was known to the natives. To the Indians white men must have been merely the subject of hearsay, for certainly none had been in contact with whites before Mackenzie's journey. Tales about white men came, rather, from the Eskimos, whose tribesmen to the west had obtained iron in trade with the Russians. A growing Russian interest in western North America had followed Bering's passage, in 1728, through the straits now named for him (Morton, 1939, p. 367; Burpee, 1935, v. II, p. 437). As the Arctic Ocean, whatever impression it made on them, filled the natives with apprehension, it was not hard for the guide to convey his distress to Mackenzie's own Indians. So strong, indeed, were his objections that Mackenzie promised not to continue toward the mouth of the river for more than seven days, and this promise at once satisfied the crew. That night they landed at 8 o'clock after travelling an estimated distance of 48 miles.

Comparison of the course directions and distances with those of the river as now known indicates that the campsite was probably on the banks of the Middle Channel at latitude 68°20′N, below the present large-meander cut-off*. This loop was still complete when Mackenzie made his journey, because it was mapped intact by Franklin in 1826-27, and Sainville's map of 1898 shows the beginning of the break-through (Franklin, 1828; Sainville, 1898; Mackay, 1963, p. 3). If this was the true location of Mackenzie's camp, his travel for the day amounted to slightly more than 80 miles.

*Saturday, July 11*—During the night Mackenzie viewed the midnight sun. Although he had been far enough north for the purpose on the preceding few nights, this was his first good opportunity to do so. Upon departure from the campsite at 3.45 a.m., the party found that, although "taking a very serpentine course," the river headed generally northwest. About 7 o'clock they could see ahead a ridge of high land—the south end of the Caribou Hills, which form the eastern margin of what is now known as the Mackenzie Delta. When the Middle Channel is followed, these first come into view at the junction with the Oniak Channel, which leads to the eastern side of the Delta (see also Mackay, *loc. cit.*). Thus it seems that Mackenzie covered 20 miles in about 3¼ hours and so moved downstream at about 6 miles an hour. Five hours later, the party landed at a site once occupied by natives. This time interval and the average rate of travel would mean that the stopping place was 30 or more miles downstream from the Oniak Channel. From the bits of whalebone, thick burned leather and spilled oil that were observed, they identified the abandoned camp as Eskimo. They assumed—especially after a fish surprised Mackenzie by jumping into his canoe—that the natives found the site attractive because of its good fishing. The place was marked by a lone tree standing "like an English May-pole" (Mackenzie, 1902, p. 260), yet islands only a few miles downstream were seen supporting no trees except dwarf willows. These observations are Mackenzie's description of the tree line of the Delta, and its location as he described it remains virtually the same.

The precise course the party took from the tree line to the sea is difficult to follow. They reached a place where "the river widens—then flows in a variety of narrow, meandering channels, amongst low islands . . . ." (*loc. cit.*). This is the section of the Middle Channel that lies at latitude 68°56′N. Here, that channel divides into three main branches, which gave Mackenzie a choice of three routes. One leads westward and empties within 25 miles into the large estuary of

*Bredin (1962) reaches the same conclusion by examining Mackenzie's distances and travel times. In addition, a plotting of the reported compass courses and their comparison with current maps shows that Mackenzie had rounded the meander loop and that his camp was about the stated latitude.

Shallow Bay. The explorer did not follow this channel, because it leads through low-lying islands and there is no high land along the route such as was reported in the journal (*op. cit.*, p. 263). A second main channel cuts eastward to Tununuk and the south end of Richards Island. This island is part of an older delta that now stands as high land northeast of the present Mackenzie Delta. The cliffs that form its sides rise 100 feet or more from the present water level and show layers of sand, silt and a little gravel. The third, or central, main distributary meanders northwest and joins the second channel below Tununuk. Mackenzie may have followed either the second or the third route but the evidence favours the central channel. If Mackenzie went via the eastern distributary, he would certainly, within a short distance, have seen the round island at Tununuk as well as the broad East Channel, which flows directly to the sea, but in his journal he mentions none of these features. The central channel, on the other hand, continues in the general direction that Mackenzie followed throughout the day and would not bring him close to the high ground until he had covered 55 more miles, or until the next day. The high ground is, in fact, described in next day's journal account. Franklin, who followed Mackenzie's journal in 1825, concluded that his predecessor took the middle north-flowing river (Franklin, 1820, p. 31).

During the afternoon, Mackenzie stopped to examine three permanent native houses built of driftwood and covered with wood, grass and branches. Part of the design involved excavation of the floor to 2 feet below ground level. Permanent dwellings thus constructed on the low land of the present Delta would be in danger of flooding. The banks of the channels are not more than 7 feet above the water; in many places they are only 5 feet high. These levels are so low that during the spring flood or prolonged periods of northwest wind, or during both, high water could force the evacuation of the camp. The rational choice of such precarious dwelling sites suggests that they offered some advantages. The availability of driftwood, present on most channels, could not have been a reason. It is more likely that the site was chosen because of its proximity to fishing grounds or to access routes to the sea and sea life.

Where Mackenzie camped on the night of July 11 it is impossible to know. Allowing for the winding route, he reckoned his day's travel at 54 miles, but he had gone farther than that by noon. The afternoon journey, broken by the campsite investigation, did not add much to the morning distance. By 8 p.m., when the party camped, they had probably covered 80 miles.

That night the uncertainty of the route and fear of the future seem to have alarmed Mackenzie's Indian companions. The guide continued to paint a bleak picture, and it was necessary to present gifts to both the guide and the English Chief to ensure their continued allegiance.

*Sunday, July 12*—In cold, damp weather brought on by the night rain, the group continued on the same meandering course as on the preceding day. At mid-morning Mackenzie found four more huts of exactly the same type as those seen the day before. They were built next to high land and dug into ground that was thawed to a depth of only 4 inches. Ground ice was apparently exposed on the hillside while snow remained in the valleys. Mackenzie observed that the ground was composed of yellow clay mixed with stones. Such deposits occur only in the higher Pleistocene delta, and Mackenzie's description probably applies to one of the outliers of the old delta now separated from Richards Island by modern distributaries. A large outlier exists on the right bank of the channel Mackenzie is thought to have followed in latitudes 69°10′N to 69°15′N.

Downstream from the Eskimo camp they came to a point where "the current was very strong," and "we appeared to have come to the entrance of the lake. The stream set to the West, and we went with it to an high point, at a distance of about eight miles, which we conjectured to be an island; but, on approaching it, we perceived it to be connected with the shore by a low neck of land. I now took an observation which gave 69.1 North latitude" (Mackenzie, 1902, p. 265).

Some 10 miles seaward from the outlier, which has been suggested as the site of the Eskimo camp, is a small eroded remnant of old delta and the last upland block before the sea. This block is today an island separated by a small shallow channel from a neighbouring fragment of the old delta. During Mackenzie's visit the separation was possibly incomplete. In any case it seems that this part of the old delta is the one where the explorer observed a latitude of 69°01′N. The true latitude is 69°22′N, the recorded position being once again far south of the true one. Mackay (1963, p. 5) suggests that in this stretch

of the journey, before reaching the last of the foregoing outliers, Mackenzie entered the series of large lakes between 69°11′N and 69°17′N and about 135°00′W. Mackenzie says they came "to the entrance of the lake" (Mackenzie, 1902, *loc. cit.*). Later, however, in reference to his heading toward "Whale Island", he says that "the lake was quite open to us to the Westward" (*loc. cit.*). If he meant the same lake in both cases, he must have been referring to the sea. Furthermore, Mackenzie was expecting to reach a "lake," probably taking this notion from his guide, who always spoke of the White Man's Lake. For these reasons it is thought that the explorer reached the Arctic Ocean by the direct channel, which separates the remnants of the Pleistocene delta from the modern alluvial deposits.

Mackenzie's journal reads as follows: "We continued the same course for the Westernmost point of a high island, and the Westernmost land in sight, at the distance of fifteen miles.

"The lake was quite open to us to the Westward, and out of the channel of the river there was not more than four feet water, and in some places the depth did not exceed one foot. From the shallowness of the water it was impossible to coast to the Westward. At five o'clock we arrived at the island, and during the last fifteen miles, five feet was the deepest water. The lake now appeared to be covered with ice, for about two leagues distance, and no land ahead, so that we were prevented from proceeding in this direction by the ice, and the shallowness of the water along the shore" (*loc. cit.*).

There is no doubt that the island upon which Mackenzie landed is the one now known as Garry Island (Bredin, 1962). To reach it, he had to maintain the same general course he had followed for the previous day. It is as he describes it, more than 150 feet high, and is the most westerly outlier of the islands north of the old delta. No high land—indeed, no island at all—lies to the west, and the open lake reported in the journal could be only the vast expanse of Mackenzie Bay. The water that Mackenzie crossed between the end of the river channel and the new island is seldom more than 5 feet deep, and in many places it is much less. Furthermore, the estimated 15 miles is about the full distance to the northwest end of Garry Island. The island's west side slopes steeply to the water, and the coast is without shelter except behind the sandspit that extends south from its northwest end. The sandspit seems to have been the only logical and safe camping place for Mackenzie's party.

When the tents had been pitched there, Mackenzie and the English Chief climbed to the nearby summit. From this observation point, about 180 feet above the sea, they looked out over the bay and saw nothing but ice extending in a wide arc from east to southwest. Far to the south, across the Delta, they saw the peaks of the Richardson Mountains, which continued northwest beyond the edge of the ice pack and gradually disappeared. These mountains—at least at their front edge—are only slightly more distant than the 20 leagues estimated by Mackenzie and are easily visible even to where they merge with the British Mountains and the whole chain curves away westward toward Alaska. To the east, the ragged northern edge of Richards Island seemed to be formed of many islands, including Pelly, Kendall and Hooper, which are well offshore. This was the grand vista that Alexander Mackenzie and his English Chief saw as they surveyed the mouth of the long river and the Arctic Sea, into which it emptied. At Garry Island they had reached the limit of their voyage.

Although this was the point from which the return journey began, there is evidence that Mackenzie still did not realize he had reached the mouth of the Grand River. "My people", he records, "could not, at this time, refrain from expressions of real concern, that they were obliged to return without reaching the sea: indeed, the hope of attaining this object encouraged them to bear, without repining, the hardships of our unremitting voyage. For some time past their spirits were animated by the expectation that another day would bring them to the *Mer d'ouest:* and even in our present situation they declared their readiness to follow me wherever I should be pleased to lead them" (Mackenzie, 1902, pp. 266–267).

The seeming lack of recognition of the Arctic Ocean probably resulted from a combination of factors. In the first place, Mackenzie could not have had a clear idea of the body of water into which his river emptied. As the journey neared its end, the Loucheux guide constantly created the impression of the party's imminent arrival at a lake (*op.cit.*, pp. 258 and 262). Even the changing landscape—low-lying country and devious river courses followed by a wide and open expanse of water—may have seemed an unlikely indication of the ultimate destination of such a drainage

system. Mackenzie had, in fact, passed through similar terrain on his way through the Slave River delta, only to find that river emptying into Great Slave Lake. In the second place, uncertainty about the identity of the new, large body of water could have arisen when it was found to be fresh and very muddy like the river itself. In the third place, because his discovery was only three nights downstream from the place where Indians had told him he would need 10 more nights to reach the ocean, Mackenzie may not have expected to arrive at the Arctic Sea so soon. He certainly knew that Hearne had arrived there seven years before at a point about 68°N, but he apparently saw no connection between Hearne's discovery and the fact that his own "lake" lay at 69°N.

The reason for Mackenzie's lack of perception may have lain partly within the man himself. On this journey he showed a reluctance to accept facts until they overwhelmed him. Not until he reached Point Separation, at the head of the Delta, did he, for instance, confide to his journal that the great river would lead to the Arctic instead of the Pacific. Yet below Camsell Bend his route lay along the base of the high mountains to the west, and everywhere he saw substantial rivers draining into the Grand River from a western divide. Furthermore, his general direction was as much northward as westward, so that each day the *Mer d'ouest* as a possible destination became more remote. Still, Mackenzie was slow in admitting the implications of this. As he stood on Garry Island looking toward a watery surface stretching north and west, he apparently had not yet found the compelling proof he needed.

*Monday, July 13*—Still hoping to continue his journey, Mackenzie waited during the day to see whether the strong winds would clear away the ice pack and so make further progress possible. Before long, the party discovered that the water was rising and had to move their gear to higher ground. The rise in the water, instead of being recognized as tide, was probably attributed to the high wind of the previous evening, which had prevented the men from checking the fish nets set, as usual, overnight (*op. cit.*, p. 266). In the nets, when they were finally reached, was a fish the size of a herring. It was of a kind unfamiliar to Mackenzie, but the English Chief recognized it as being of a type caught in Hudson Bay. Thus evidence continued to mount that this was not a lake but the ocean.

Mackenzie took observations on his position again, this time fixing the latitude at 69°14′N. Later dead reckoning determined the longitude at 135°W (*op. cit.*, p. 268). The true co-ordinates of the spit on which they may have camped are 69°29′N and 135°48′W. Thus the discrepancy in latitude amounted to 15 minutes; the explorer's previous observation in the Delta had been out by 21 minutes.

Mackenzie retraced his steps to the island's summit and found that the strong wind blowing since noon had failed to move the ice pack. This time, however, he "could just distinguish two small islands in the ice, to the North-West by compass" (*op. cit.*, p. 269). His description is not clear as to why they were barely distinguishable—because of their distance, size and height above the ice pack or because of the weather. Their alleged size and the compass direction may mean that they were two small islands a mile or two from the land on which Mackenzie stood. The corrected direction of his compass observation would be approximately north, toward where two large sand bars stand above the water level. It is possible that these bars were islands in Mackenzie's time but were subsequently eroded by the sea. Marine erosion in this area is greatly accelerated by the melting of wave-exposed ground ice and frozen sands and muds.

*Tuesday, July 14*—In the morning the men followed some whales in their canoes but were prevented by the fog from capturing or killing any. So far as the party could see, the whales were all white, and Mackenzie likened them to porpoises. As they were much larger, however, than the largest porpoise, Mackenzie considered it fortunate that the fog had intervened. Today the areas around the north and east sides of Garry Island are favourite places for hunting white whales. The presence of these animals may have suggested to Mackenzie that he had reached the sea, but he does not say so in his journal.

At noon, when the fog lifted, they embarked to examine the ice, but a sudden northeast wind and returning fog forced them to retreat, and with difficulty they found shelter behind their island. In the journal Mackenzie says that "we continued our course along the islands, which screened us from the wind . . . in the hope of meeting with parties of the natives . . .. At eight we encamped on the Eastern end of the island, which I had named Whale Island" (*op. cit.*, p. 271). The islands in question are possibly the two

small islands described earlier, since they could protect the canoes from a wind of northeast compass direction. They are also close enough to Garry Island to permit a safe return because, as Mackenzie says, he landed on the island that he had named Whale Island. Whale Island and Garry Island are one and the same. The description given by Mackenzie—7 leagues long and half a mile broad and oriented east-west by compass—compares favourably with that of Garry Island, which is 7 miles long and between half a mile and 2 miles across and is oriented northwest-southeast. Magnetic variation accounts easily for the differences in direction (Mackay, 1963, p. 6; Bredin, 1962, p. 59). The camp made at the end of Garry Island was probably on the present southeast sandspit. Mackenzie mentions that there were five or six very old huts at this place (Mackenzie, 1902, p. 271). Neither huts nor other evidence of former occupancy can now be seen, having been eliminated by shore processes that are causing the sandspit to migrate eastward or buried by downslope movement in the active layer.

Mackenzie then realized that he could not proceed farther north and, before starting the return journey, "ordered a post to be erected close to our tents, on which I engraved the latitude of the place, my own name, the number of persons which I had with me, and the time we remained there" (*loc. cit.*).

*Wednesday, July 15*—About 4 a.m. Mackenzie awoke to discover that the water had risen for the second time and was wetting the gear and that on this occasion the rise was accompanied by a strengthening of the wind. He was aware that the tide might be the cause and continued to watch its rise until 6 o'clock. Uncertain of his position and unable, besides, to leave because of the wind, he determined to remain overnight to check his observations. Although the southeast sandspit is actually at 69°27′N, a noon latitude reading gave 69°07′N. Thus another southerly error in Mackenzie's observations, this one amounting to 20 minutes.

Now that he had seen whales, fish like those in Hudson Bay, landless water stretching away to the northwest and what appeared to be a tidal rise and fall, Mackenzie must have known that he had reached the ocean. Although he did not record this conclusion in his journal, it was clear that the return journey, now pressed upon him by time and the dwindling of his supplies, would have to be undertaken with the doubtful distinction of perhaps having discovered the Arctic Sea. The hope that the new route would lead to the *Mer d'ouest* had proved to be completely groundless, and the explorer's consequent disappointment seems to have overshadowed any enthusiasm he may have felt at the prospect of trade along the great newly discovered route. Within his lifetime, however, Mackenzie's river became an avenue of prosperity both for him and for his Northwest Company associates.

*Thursday, July 16*—Bad weather during the night and morning caused uncertainty about the accuracy of the observations of tidal range, which measured about 16 to 18 inches. When he had completed the measurements, Mackenzie "embarked, and steered under sail among the islands" hoping to encounter natives, but he soon gave up and "accordingly made for the river, and stemmed the current" (*op. cit.*, p. 273). The route "among the islands" was probably a passage leading eastward toward Kendall Island. When the explorer decided to start his return trip, he could have entered any of the two or three channels opening southeast of Kendall Island, all of which join upstream into one river flowing at the base of the high land of Richards Island. The water was so shallow that the travellers could use their paddles as poles, pushing with them on the bottom. They camped at 7 p.m. Since there is no indication of the distance covered during the day, it is impossible to tell what progress was made. The party may have reached the base of the high ground at Richards Island. Once they were away from the cold sea water and among the Delta islands, there was a noticeable rise in temperature, but this compensation was marred by clouds of mosquitoes.

*Friday, July 17*—The group took to the water at 4 a.m., and the routine of long, hard days began again. Passing next to Richards Island, they missed the entrance to the stream that connects directly with the Middle Channel and so moved upstream along the island edge directly toward Tununuk. This route is not now navigable except at high water, although it may have been passable in Mackenzie's time (Mackay, 1963, p. 7). At the south end of Richards Island they "landed upon a round island, close to the Eastern shore, which possessed somewhat of a sacred character, as the top of it seemed to be a place of sepulture, from the numerous graves we observed there" (Mackenzie, 1902, p. 274). The island so

described is at Tununuk. It has also been locally known as "Devil's Island", because in the past it was a place of burial. Recent graves are visible on its highest ground.

They now progressed upstream via the East Channel and soon saw the first spruce trees both on the islands and in the sheltered valleys along the edge of the Caribou Hills. The presence of trees surprised Mackenzie since the ground had not thawed deeper than 5 inches from the surface. After pitching camp on the east side of the river, Mackenzie climbed to the flat top of the flanking hills and "had a delightful view of the river, divided into innumerable streams, meandering through islands, some of which were covered with wood, and others with grass. The mountains (Richardson Mountains) that formed the opposite horizon, were at the distance of forty miles. The inland view was neither so extensive nor agreeable, being terminated by a near range of bleak, barren hills, between which are small lakes or ponds, while the surrounding country is covered with tufts of moss, without the shade of a single tree" (*op. cit.*, pp. 275–276).

The location of Mackenzie's campsite cannot be fixed precisely. It is certain that the group had passed south of the treeline. Along the East Channel the first trees appear only 5 or 6 miles south of Tununuk, on the two large mid-channel islands. A few miles upstream spruce trees occur in the mainland valleys but, as the explorer observed, not on the hilltops. On this basis, the camp was probably set on the east bank 12 miles or so upstream from Tununuk. From this location in the Caribou Hills the view of the Delta and the inland areas is very much like that described in the journal.

*Saturday, July 18*—The travellers began their day at 3 a.m., and did not camp until 7 p.m., thus working altogether 16 hours. Mackenzie walked most of the day along the edge of the hills in the company of the English Chief, while the rest of the party brought the gear and canoes up the East Channel against the 2 mph current. The walking was arduous because, although the land was elevated and the ground had thawed no deeper than 6 or 8 inches, the surface was frequently wet and marshy. By maintaining a rigorous pace throughout the day, they might have accomplished 30 miles. Their route followed a fairly straight line along the edge of the Caribou Hills, past what is now Reindeer Station, to where the hills lose their identity in the general level of the country near the south end of Harrison Island. Mackenzie reported that "the face of the high land, towards the river, is in some places rocky, and in others a mixture of sand and stones, veined with a kind of red earth, with which the natives bedaub themselves" (*op. cit.*, pp. 277–278). Red beds are still visible as horizontal bands along the hillside and appear to have resulted from the burning of peat or some other organic deposit.

*Sunday, July 19*—Rain and strong wind from the north delayed the usual early departure until after 8 a.m. During the stormy night, the native guide, perhaps feeling more secure after returning to forested land, deserted to make his way back alone. When the weather cleared, Mackenzie chose to follow the East Channel and so keep close to the mainland. This route, being narrower than the wide Oniak Channel, which leads to the main stream of the river, had a more gentle current against which he could move with greater ease. At a place identified only as one previously occupied by Indians, they camped at 8 o'clock. If they covered as much distance as on the previous day, this campsite must have been in the vicinity of the present new townsite of Inuvik.

*Monday, July 20*—The party broke camp at 3 a.m., but heavy rain forced them to stop at 2 p.m., after they had passed the stream where Mackenzie expected to meet Eskimos. The suggestion has been made that this was the Campbell River. It is the only sizable tributary entering the Delta from the east and, moreover, drains Campbell Lake and is part of a portage route through Sitidgi Lake to the south end of the Eskimo Lakes. Along such a natural route the natives would find a logical meeting place.

It is not possible to pinpoint where Mackenzie camped on this date. In 11 hours' travel against the current, the party could scarcely have gone, at best, more than $2\frac{1}{2}$ to 3 mph, or about 30 miles in all. This would take them past the Campbell River to a point about 35 miles downstream from Point Separation. A campsite in that vicinity could fit the description Mackenzie gave when he said that "the ground close to the river does not rise to any considerable height, and the hills, which are at a small distance, are covered with spruce fir and small birch trees, to their very summits" (*op. cit.*, p. 279).

*Tuesday, July 21*—As the storm of the previous afternoon had shortened the day's travel,

Mackenzie embarked at 1.30 a.m., much earlier than usual. He followed the East Channel until 10 o'clock, then "left the channels formed by the islands for the uninterrupted channel of the river, where we found the current so strong, that it was absolutely necessary to tow the canoe with a line" (*loc. cit.*).

This procedure was carried out as follows: Two men went on shore and towed for two hours. Those remaining in the canoe helped with the paddles to keep the boat in water deep enough to avoid boulders and other obstructions. Then another two would take up the line for a new two-hour shift. At first, where the banks along the main flow of the Mackenzie are low the party found walking on shore reasonably easy, but when they reached the Lower Ramparts, above the Arctic Red River, their progress became increasingly difficult (Figure 4). "The land on both sides was elevated, and almost perpendicular, and the shore beneath it, which is of no great breadth, was covered with grey stone that falls from the precipice" (*loc. cit.*). Besides the physical strain of walking and pulling against a strong current over unstable slopes of sharp fragmental talus, they experienced danger from these falling rocks. Yet they made good time and at 8.30 that night camped on the east side of the river at the site they had occupied on the downstream journey 12 days before. The day's journey probably covered about 50 miles.

*Wednesday, July 22*—With an early start, at 3.30 a.m., the arduous towing continued along the east shore. Mackenzie walked with natives who had visited his camp the night before and, after three hours of difficult travelling, he reached their huts. They passed a narrow, deep river, probably the one now known as Pierre Creek, where the Indians had set nets. While with the natives, Mackenzie observed their way of life and had the English Chief question them about their circumstances and their land. From this he learned of the enmity between the Indians and the Eskimos, and also that the Eskimos had traded iron with white men in the vicinity of *Belhoullay Toe** (White Man's Lake—that is, along the Arctic coast).

For most of the day, with the exception of short periods when the wind was right for sailing, travel was by means of the towline. Before pitching camp again, the party toiled for 16½ hours. Although the travellers started on the east bank, it cannot be known positively whether they camped on it that evening because, while using sails, they could have changed from one side of the river to the other. Calculated from the known travel time and distance between the camps of July 21 and 23, their average rate of progress was 3½ mph. On this basis their day's distance would be 55 or 60 miles. Thus their camp for the night was probably 10 miles or so downstream from the Travaillant River.

*Thursday, July 23*—The pace Mackenzie set for his party was exhausting. Again, after beginning at 5 a.m., he forged on for 15 hours. Throughout the day the party had difficulty in proceeding along the beach and had, at all times, to employ the towline against the strength of the current. By 8 p.m., however, they were able to stop at a familiar campsite, the one occupied on July 8, which was probably on the east bank of the Mackenzie about 5 miles upstream from the Thunder River. This day brought the party about 50 miles nearer to their home base.

*Friday, July 24*—The men began to work at 5 a.m., and at first it seemed that the tedious towing of the previous day would be repeated. After 10 o'clock, however, before a favourable breeze, they were able to stow the towline and employ sails and paddles. In the early morning, while working their way along the east shore, they passed a small stream on either side of which the natives collected flint. "The banks are high, steep, and soft rock, variegated with red, green, and yellow hues. From the continual dripping of water, parts of it frequently fall and break into small stone flakes like slate, but not so hard. Among them are found pieces of *Petrolium*, which bears a resemblance to yellow wax, but it is more friable" (*op. cit.*, p. 287). Hume locates this place at the Lower Ramparts (Hume, 1913, p. 81). To anyone who has followed Mackenzie's progress thus far, however, it should be clear that the description refers to a site upstream from the Lower Ramparts, probably near McBride's cabin or the former Little Chicago trading post. As the rocks of this region are of the same age as the strata at Norman Wells, the presence of petroleum is credible even though never substantiated.

The travellers camped that evening at 7 o'clock, but the site of their encampment cannot be located. If they averaged about 3 mph on this

**Belhoullay Toe* is the same as *Benahullo Toe* (p. 228), and both spellings are used by Mackenzie (*op. cit.*, pp. 258 and 285). The meaning is "White Man's Lake". The words themselves are probably Mackenzie's version of the Loucheux Indian rendition of the Eskimo term (*loc. cit.*).

long day—and, as they had the aid of the wind, they may well have done so—they would travel at least 40 miles and their camp would be in the vicinity of, or downstream from, the mouth of the Ontaratue River.

*Saturday, July 25*—On this day, which for Mackenzie began at 3.45 a.m., the men found the current slack enough to make headway with paddles and so avoid the difficulties and danger of towing canoes through the shoals at the river's edge. "The inland part of the country is mountainous and the banks of the river low, but covered with wood" (Mackenzie, 1902, p. 290). It is true that the land east and north of the river rises in a broken and semimountainous fashion, but the river banks on the same side are not low. In places they are more than 200 feet high. On the opposite side, however, the banks are consistently low, and the interior to the west and southwest rises gradually away from the river. Perhaps Mackenzie's brief description was meant to cover the land on both sides of the river.

An approaching thunderstorm forced a landing just after 7 p.m. It broke before camping operations were completed but, although very severe, was short-lived. The travelling time for the day was almost 16 hours, and the distance accomplished was about 40 miles. The probable campsite was some 10 or 20 miles downstream from the Loon River.

*Sunday, July 26*—The account of the country kept by Mackenzie on his return journey is very incomplete. It is therefore difficult to assign particular days of travel to particular segments of the river. July 26 is especially difficult. The explorer gives the only clue to his precise location when he relates that "we passed a river of some appearance, flowing from the Eastward. One of the natives who followed us, called it the Winter Road River" (*op. cit.*, p. 293). The stream best fitting this description is the Hare Indian River, which enters the Mackenzie near present-day Fort Good Hope. It is a broad stream following an old drainage channel from the Smith Arm of Great Bear Lake, to which it is a natural route. Tributary access streams lead to Lac Belot and Colville Lake or to the Carnwath and Anderson rivers and the Arctic coast. Any of these routes could have been the natives' "Winter Road". What Mackenzie described might, on the other hand, be the Loon River, which is farther downstream. It is not large, but its wide mouth seen from the Mackenzie would make it appear so. Upstream it gave natives access to the Iroquois River or the Carnwath, both of which drain into the Anderson River and so to the coast. As a route for inland penetration, however, the Loon River is less desirable than the Hare Indian.

The evening camp was probably near the site of Fort Good Hope or 15 miles downstream.

The day was not important for the distance accomplished, but contact with the natives brought intelligence that became a driving force in Mackenzie's life over the next few years. A Dogrib Indian living among the Hare Indians in this area told a tale, which the explorer set down as follows:

"He had been informed by the people with whom he now lives, the Hare Indians, that there is another river on the other side of the mountains to the South-West which falls into the *Belhoullay Toe*, or White-man's Lake, in comparison of which that on whose banks we then were, was but a small stream . . . that those who inhabit the entrance of it kill a kind of beaver, the skin of which is almost red, and that large canoes often frequent it. As there is no known communication by water with this river, the natives who saw it went over the mountains" (*op. cit.*, p. 292).

Mackenzie took this description to mean a way to the western sea, the object of his search. He might have recognized the red-skinned beaver as the sea otter, but he was certain that the large canoes were ships of trade from Russia or Britain. From here upstream, he was eager to gather all available information concerning a course through the mountains to connect with this river that led to the *Belhoullay Toe*.

*Monday, July 27*—Taking every opportunity to amplify and confirm the native report of the previous day, Mackenzie stopped at an Indian camp below the rapids—near The Ramparts. From the journal entry for the following day, it seems that Mackenzie must have camped downstream from The Ramparts and that he could not have accomplished much travel in the five or so hours he had on the water.

Upon questioning the natives, he found that they had no first-hand experience of any river across the mountains. They had never ventured beyond the range immediately west of the river. He nevertheless learned the following:

"They had, however, been informed that it (the river to the west) was larger than that which washed the banks whereon they lived, and that

its course was towards the mid-day sun. They added, that there were people at a small distance up the river, who inhabited the opposite mountains, and had lately descended from them to obtain supplies of fish . . . . I engaged one of them . . . to describe the circumjacent country upon the sand. This singular map he immediately undertook to delineate, and accordingly traced out a very long point of land between the rivers, though without paying the least attention to their courses, which he represented as running into the great lake, at the extremity of which, as he had been told by Indians of other nations, there was a Belhoullay Couin, or White Man's Fort. This I took to be Unalascha Fort, and consequently the river to the West to be Cook's River; and that the body of water or sea into which this river discharges itself at Whale Island, communicates with Norton Sound. I made an advantageous proposition to this man to accompany me across the mountains to the other river, but he refused it" (*op. cit.*, pp. 294–295).

Another group of natives farther upstream, when asked about the river to the west, gave a similar answer. "They likewise mentioned that the sources of those streams which are tributary to the great rivers are separated by the mountains" (*op. cit.*, p. 297). Without success, Mackenzie tried to pursue discussion about this new river. He later concluded: "I now found that it would be fruitless for me to expect any accounts of the country, or the other great river, till I got to the river of the Bear Lake, where I expected to find some of the natives who promised to wait for us there. These people had actually mentioned this river to me when we passed them, but I then paid no attention to that circumstance, as I imagined it to be either a misunderstanding of my interpreter, or that it was an invention which, with their other lies, might tend to prevent me from proceeding down their river" (*op. cit.*, p. 299).

The tales concerning the great river flowing to the west had passed through the cultural contacts of several nations of Indians. As they did so, details were magnified, distorted or forgotten. On reaching Mackenzie, at third or fourth hand at least, they contained little more than Mackenzie already knew of the north Pacific coast. It is not surprising that the crude sand map sketched on mere hearsay by a native untutored in drawing should lead Mackenzie to just the kind of conclusions he wanted to reach. Under the circumstances, it was logical that the new river should join "Cook's River" and that the fort should be Unalaska. Since the source of information was in the lower Mackenzie valley, a great river west of the mountains could be nothing but the Yukon and its tributaries. Moreover, the point of land separating the mouth of this stream from Mackenzie's river represented the prevalent hazy notion of the northern half of Alaska. Mistaking this point for the entire Alaska peninsula, Mackenzie naturally assumed that the fort was Unalaska, a Russian post situated on an island of the Aleutian chain. The natives were probably referring, rather, to a Russian trading place at the mouth of the Yukon, not to a permanent settlement known to Mackenzie. He correctly concluded, however, that water communication was possible between the mouth of his Grand River and Norton Sound. Information indicating that the mountain chain to the west was the divide between two great rivers must have disappointed Mackenzie, but he was now on the alert for a stream that would be likely to facilitate effective penetration toward his western goal.

It is noteworthy that the first indication of a route westward should come from the northern end of the country. When, on his downstream passage, the natives at the Great Bear River told Mackenzie about such a waterway, he dismissed the news as just another fantastic Indian tale. How word of the western sea reached the Mackenzie Indians is no more than a matter of speculation. To the west, however, there is contact through the Peel River drainage system, the route that eventually became the fur traders' way to the Yukon. Contact may also have been made through the passes between the Mackenzie River tributaries and the Stewart or Pelly River drainage system.

The distance travelled during the five-hour day was perhaps no more than 15 miles. This would place the evening camp at the lower end of The Ramparts.

*Tuesday, July 28*—The journal entry for the day provides fairly precise information about one location along the route. "This is the place that the Indians call a rapid, though we went up it all the way with the paddle; so that the current could not be so strong here, as in many other parts of the river; indeed, if it were so, the difficulty of towing would be almost insuperable, as in many parts, the rocks, which are of a great height, and rather project over the water, leave no shore between them and the stream" (*op. cit.*, p. 302).

The description fits The Ramparts, above Fort Good Hope, where the flow in the narrow channel is remarkably slack along the shore and paddling upstream is possible.

The working day lasted for the usual 15 hours or so, but much of it was spent in visiting native campsites along the river. Most of these had been temporarily abandoned as news spread of the party's approach. Some of the natives were found, but only supplies of food resulted from these short visits. There was no further information. Upriver from The Ramparts the stream is wide and full of shifting islands, and Mackenzie describes no distinctive topography to help measure his progress. He camped at 8 o'clock, probably about 10 miles upstream from the Hume River.

*Wednesday, July 29*—At 4.15 a.m. the group embarked in a cold but suitable wind that carried them upstream under sail at a good rate. They soon reached Sans Sault Rapids and worked their way over the shallow ledges on the west side of the river. The change that had occurred in the water level since the beginning of the month was quite noticeable, and the upward passage was much more difficult. Mackenzie estimated that the river had dropped 5 feet (*op. cit.*, p. 303). The western passage around the rapids brought to their attention the mouth of the Mountain River, and it appeared to Mackenzie to be the largest stream flowing from the west with the exception of the Liard River. This, of course, is not true. Observation of river mouths gives only the crudest estimate of flow volume or basin size.

The day's travel lasted about 15 hours. On the basis of an average of 2 mph, the evening camp was probably 30 miles upstream from the last one, or 10 miles above East Mountain.

*Thursday, July 30*—The routine of travel began at 4 a.m. and continued until 7 p.m. Mackenzie used his sails to take advantage of a following wind, and the canoes made good progress, especially in a part of the river where the current was slack. The camp for the night was probably a little upstream from where the river widens and flows about several large islands (Figure 3). This is about 20 miles downstream from present-day Norman Wells. Mackenzie does not mention the spectacular view of the nearby Norman Range. It has been suggested, especially as 10 years elapsed before the journal was published, that in the decade following the voyage much of the detailed description of the country was deleted.

*Friday, July 31*—The unsettled weather of the preceding days lasted throughout the night but subsided at 9 a.m. Thus it became possible to continue the journey. The wind remained favourable (blowing upstream), at least until late in the afternoon, when the skies cleared and the wind dropped. Mackenzie had intended to keep close to the western shore in hopes of discovering a large tributary, but shoals prevented a close approach. The reference to shoals helps to fix the sector of the river passed on this day, because opposite Norman Wells, and for some 10 miles downstream and intermittently upstream, sand and gravel bars make the west bank hard to approach. In the cutbanks or where recent slumping had occurred, Mackenzie observed ground ice that extended to within a foot of the upper surface. Permafrost, sustaining ground ice, is only locally continuous in this part of the river valley (Brown, 1960). The long day—they camped just before 8 o'clock—probably brought them an additional 30 or so miles closer to their destination or somewhere near Ten Mile Island, 10 miles above Norman Wells.

*Saturday, August 1*—Mackenzie continued his journey at 3 a.m. and seems to have kept to the west side of the river for most of the day. He encountered one group of Indians, but their menfolk were away hunting, and no further information concerning the western river was forthcoming. Mackenzie suspected that this interpreter had withheld information to keep it from influencing him to follow another course instead of returning to Fort Chipewyan. That night the travellers camped on the west side of the river, under Bear Rock, occupying the same campsite as on July 5. For the first time on their southward trip, the sky was dark enough for them to see the stars.

*Sunday, August 2*—The wind having changed, the men were forced once again to revert to the towline. On the way to the Great Bear River, which they reached in a short time, Mackenzie noted mineral springs near Bear Rock and lumps of what he believed to be iron ore. The Indians he had expected to meet at the river were not present, and he continued upstream toward smoke he believed to come from native camps. He discovered, however, that the smoke was from fires burning deep in lignite seams along the east bank. Perhaps his iron ore was the reddish residue left



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by this combustion. Smoke from the fires was later observed by Franklin and Richardson, and present-day travellers may see it on occasion as it rises from the fires that erupt intermittently. Farther upstream, they saw recent native encampments and made their own camp nearby. Later in the day Mackenzie sent his men in search of local Indians, but the search could not go beyond a large lake that the men encountered inland from their camp. There are two large lakes near the bend of the Mackenzie River 10 miles upstream from Fort Norman. The camp may have been in this vicinity.

*Monday, August 3*—During this and the next seven days Mackenzie and his party pursued the upstream course from the Great Bear River to Camsell Bend. The daily distances accomplished can be estimated only by matching the time of travel against the total distance and taking into account the characteristics of the river current. Small hints in the journal give a slight indication of the explorer's progress. The group began to travel at 4 a.m. and reached Old Fort Point probably about noon. That was the time of day at which Mackenzie noted the acceleration that takes place in the current near the point. They continued to tow the canoes along the east bank to avoid the serpentine passage of the west shore. The day, which ended 16 hours after the morning start, brought the party above the confluence of the Mackenzie and the Keele, or "Gravel River".

*Tuesday, August 4*—After a cold night, Mackenzie and his men worked upstream along the gravel-strewn beaches against the strong current characteristic of this island-dotted, shoal-strewn part of the river. They camped at 5 p.m. and probably settled for a narrow beach between the Dahadinni and Blackwater rivers.

*Wednesday, August 5*—The journal entry gives no indication of their geographic location. Mackenzie mentions that they proceeded with great difficulty, and 25 miles by towline would presumably be good progress. They may have reached a point about the mouth of the Johnson River.

*Thursday, August 6*—Rain delayed departure until after 6 a.m., but the wind then shifted so that it became possible to change from dreary trudging along the riverside to hard paddling and the use of the sails. The route now lay over a narrow, deep section in which the current is slack. Under these circumstances they may have passed the site of Wrigley before 6 p.m., when they camped (Figure 2). Mackenzie failed, however, to mention Roche-qui-trempe-à-l'eau, where they camped on the downstream journey.

*Friday, August 7*—Although it does not say so outright, the journal account gives the impression that the men were once again towing the canoes. Between Wrigley and the River Between Two Mountains, particularly near the latter, the current is so fast that it is compatible with Mackenzie's description of currents flowing "along the points" and being "equal to rapids" (Mackenzie, 1902, p. 312). Progress was much reduced by fast water and the toil of scrambling over stone-covered beaches below the high banks. They camped that night "at the entrance of a small river" (*loc. cit.*). The two shreds of evidence—fast water and the river mouth—suggest that the campsite was at the River Between Two Mountains.

*Saturday, August 8*—Mackenzie and his party remained in camp throughout the day to allow his hunters to replenish the food supply. Moreover, the weather was unsuitable for travel.

*Sunday, August 9*—The rainy weather of the preceding few days brought a rise in the water level and strengthened the flow against which Mackenzie's men had to struggle. They pushed on upstream, beginning at 3.30 a.m. and continuing until 7 p.m. During the day, the party must have passed the south end of the McConnell Range, which rises east of the river. Mackenzie again failed to record the existence of the Willowlake River; he may have missed it altogether by taking the western channel past McGern Island. The group probably camped in the vicinity of this island.

*Monday, August 10*—Neither by native description nor by his own observations had Mackenzie ever been able to amplify what he had heard about the river to the west. As the mountain chain to the west and the great river approached each other, he therefore planned to climb the Camsell Range for a vantage point from which to survey the countryside. Accordingly, he landed the canoes on the west side at Camsell Bend and, with an Indian companion, hiked toward the peaks. The excursion was a failure because swampy ground lying between the mountains and the river prevented him from gaining his objective. The poorly developed drainage of the valley floor was, and would continue to be, an obstacle to exploration back from the river.

*Tuesday, August 11*—During the day Mackenzie made every effort to meet some of the local natives, none of whom his party had seen since leaving The Ramparts. From them he wished to learn more of the western river. As the travellers progressed upstream, they worked back and forth between the west and the east bank and spent several hours tracking natives along the shore. At the same time Mackenzie's own companions, the English Chief in particular, were giving him less and less co-operation. The men still feared that they might be led on a side excursion to find the fabled river instead of returning directly to Fort Chipewyan. The campsite chosen that evening was probably some 20 miles upstream from the mouth of the North Nahanni River.

*Wednesday, August 12*—For an efficient search of both sides of the river, Mackenzie directed two of his Indians to follow the south shore. The remainder looked for local inhabitants on the north shore. The day passed, and no Indians were seen. The group camped early at a site not identified in the journal. On the basis of previous distances, it may have been 25 miles upstream from the last campsite.

*Thursday, August 13*—The group resumed their travel at 3.30 a.m. and retrieved the cache left on a neighbouring island on July 1. While subsequently pushing upstream, they noted several places that had been occupied by Indians. That night the party camped at the mouth of the Liard River, probably on the flats below the island on which Fort Simpson now stands. At this time of year the low water level exposes extensive shoals along the south side of the river and around the island. The island itself was seen to be covered with a whitish salt deposit.

*Friday, August 14*—Before continuing, Mackenzie examined the mouth of the Liard River by travelling in it a few miles upstream, crossing and returning along the opposite shore. He remarked on how very muddy was the water of this river and was now aware that the two streams —the muddy Liard and the clear Mackenzie— instead of blending immediately, continued to flow side by side for some miles below their confluence. Mackenzie did not seem to realize that the Liard, which leads through the mountain ranges to the headwaters of the Yukon, might be his western river, and he abandoned it after this cursory examination.

Upstream from the mouth of the Liard, the main river is confined to a narrower channel and flows more swiftly. Walking over bouldery beaches at the base of high banks was difficult. It seems reasonable to assume that, while going upstream after passing the Liard, the party remained on the southwest shore. Mackenzie did observe that a river entering from the opposite side, probably the Rabbitskin River, appeared navigable, and his camp must have been nearby.

*Saturday, August 15*—The whole day was spent in hauling the boats upstream against the strong current. The camp for the night was probably about 10 miles below Head-of-the-Line.

*Sunday, August 16*—In the cold early morning hours Mackenzie's group took up the towlines once again, proceeded slowly along the narrow beach and reached Head-of-the-Line within a few hours. Here the widening of the river is accompanied by a slack current, but they were able to use their paddles and "proceeded upon it (the current) almost as fast as in dead water" (*op. cit.*, p. 323). No mention is made of their campsite, but it was probably some miles upstream from the Trout River and on the north bank, which is less swampy and has deeper water inshore than most of the south side of this section of the river.

*Monday, August 17*—Because the paddlers had to work against a strong, swift current, the pace of the day's upstream progress was much reduced. The length of the working day, 3.30 a.m. to 7 p.m., was typical, however, of the leader's perseverance. Among the things Mackenzie noted as he advanced were lodges, which, from their structure, he took to be those of the Red-Knife Indians. The evening camp was the one at the outlet of Mills Lake occupied on the night of June 29 (Figure 1).

*Tuesday, August 18*—The land on the north shore of Mills Lake is low and swampy, and the lake itself is very shallow away from the main river channel, which passes along the southern edge. In the early morning Mackenzie ventured across from his camp on the southwest shore. On the north edge he observed the latitude and found it to be 61°33′N, which is only a few minutes north of the true position. He then canoed southeast, probably along the east shore of the lake, and later passed the mouth of a small channel. As the provisions were low, his Indian companions had to take time for a hunting ex-



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cursion. Consequently, no effort was made to cover a great distance. The party camped on one of the islands north of the main stream.

*Wednesday, August 19*—Mackenzie's course for the day is difficult to reconstruct, but it is clear that he continued to delay progress in favour of hunting expeditions. In his own travel, which lasted only four hours, he presumably followed the island-studded channel upstream toward present-day Fort Providence.

*Thursday, August 20*—The travellers began to move at 4 a.m. and followed a course that led past what is today the site of Fort Providence. They kept to the north side, tolerating its strong current so that Mackenzie could observe the mouth of the Horn River, which he knew from his downstream journey to be in the vicinity. He soon, and correctly, identified this river with the channel he had passed on the preceding Tuesday. He then crossed to the south side and experienced the stronger current of the Providence Rapids. At half past seven the party camped on the low banks of the north side about 20 miles farther upstream.

*Friday, August 21*—Bad weather, including rain and a strong east wind, prevented moving the canoes. Mackenzie therefore remained in camp while his hunters searched the neighbouring forests.

*Saturday, August 22*—When the storm passed, the wind veered to the west. Thus enabled to employ sail, the party reached the edge of Great Slave Lake via the North Channel in three hours. If they had paddled, the same journey would, according to Mackenzie, have taken eight hours. For the moment, the canoes were prevented by strong wind and rough water from proceeding into the lake. They were now poised, however, awaiting an opportunity to enter it for the return journey via the same north-shore route and the Slave River to Fort Chipewyan.

The following day Alexander Mackenzie left the Grand River, which would eventually bear his name, but for him it was the "River of Disappointment." Instead of leading, as expected, to the western ocean, his route led north to a frozen sea. He had spent 55 days on its course—two weeks following it downstream and the remaining 31 days returning against the current. The time spent away from Fort Chipewyan was 102 days. In the context of exploration, the journey is a remarkable one and a very great achievement. Mackenzie's success lies, of course, in the discovery of the river rather than in its geographical description, but in accomplishing his task he showed wisdom, courage and steadfastness. In one summer he extended the known land of his day by more than a thousand miles and fixed another point on the Arctic coast of North America. The new waterway shaped the approach and successes of subsequent explorers such as Franklin, Richardson and Rae, or Simpson and Dease. Its discovery, moreover, gave Mackenzie the experience, knowledge and notions that impelled him to pursue his quest to the Pacific coast.

## ACKNOWLEDGMENTS

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# POSTGLACIAL EMERGENCE AT THE SOUTH END OF INUGSUIN FIORD, BAFFIN ISLAND, N.W.T.

*Olav H. Løken*

ABSTRACT

A beach deposit from Inugsuin Fiord, Baffin Island, is described and its mode of formation outlined. It was possible to relate a number of shell samples to the sea levels prevailing when the shells lived. An accurate emergence curve has been drawn which is similar in form to curves obtained from other areas. The early part of postglacial time was characterized by a rate of emergence much smaller than observed in other areas and there are distinct differences between the pattern of emergence on the west and the east coasts of Baffin Island.

A pronounced bench on the beach deposit is discussed and is believed to be associated with a postglacial halt in the process of emergence. This is possibly a parallel to a postglacial transgression in northern Labrador and of late Tapes age. Fossil evidence suggests a climate in early postglacial time warmer than the present.

RÉSUMÉ

L'auteur décrit un dépôt de plage du fjord Inugsuin, Île Baffin (T. N.-O.) et expose son mode de formation. Il a été possible de rattacher un certain nombre de coquillages fossiles à différents niveaux de la mer à l'époque de leur vie. L'auteur a tracé une courbe précise d'émersion, d'une allure semblable aux courbes d'autres régions. Le début des temps post-glaciaires a été caractérisé par une vitesse d'émersion beaucoup plus faible que celles qui ont été observées ailleurs. L'allure générale de l'émersion sur la côte ouest de l'Île Baffin diffère nettement de celle de l'émersion sur la côte est.

L'auteur étudie l'existence d'une terrasse bien marquée qu'il croit causée par un arrêt dans le mouvement d'émersion postglaciaire. Cette terrasse semble correspondre à une transgression marine postglaciaire, d'âge Tapes récent, dans le nord du Labrador. Les indices fournis par les fossiles font croire que le climat du début des temps postglaciaires était plus chaud qu'actuellement.

## INTRODUCTION

The postglacial isostatic recovery of glaciated areas has been studied in many localities and several curves to show the vertical displacement of the shoreline as a function of time have recently been published (Blake, 1961; Farrand, 1962; Feyling-Hanssen and Olsson, 1959; Henoch, 1964; Ives, 1964; Washburn and Stuiver, 1962.) These curves have been based on radiocarbon dates of marine mollusc shells, whale bones, driftwood, peat deposits and from archaeological sites.

Ives (1964) lists some of the errors that might be inherent in such curves, i.e., errors in the dating process, contamination and possible redeposition of the shells, the difficulties of assessing the depth at which the molluscs originally lived and finally the inaccuracy introduced by the usually limited number of observations on which a given curve is based. Although the discussion was restricted to marine molluscs, the same applies to other organic deposits such as driftwood, whale bones and peat deposits. An additional error is introduced because dates on which some curves have been constructed were derived from widely separated localities without proof that a comparison could be made.

This paper presents the results of a detailed study of a raised shore feature in Inugsuin Fiord, Baffin Island (Figure 1) carried out during the summer of 1964. Radiocarbon dates have been obtained from shell samples and their faunal

MS submitted May, 1965.

FIGURE 1. Location map.

composition provides information about ecological conditions in postglacial time. (In this paper, postglacial time means the time since deglaciation of the locality in question.) The height of sea level at the time the shells lived has been accurately determined from their stratigraphic position and all samples are from a small area; none of the sampling sites is more than 700 metres from another.

On this basis, a curve showing time versus height of sea level above present sea level has been drawn. This curve shows the time when any point below the marine limit emerged above sea level and the slope of the curve shows the rate at which the land emerged from the sea.

Such a curve will be referred to as an emergence curve, a better term than the commonly used "uplift curve". It is proposed to reserve the latter for a curve showing crustal uplift, that is the time change of geocentric distance for a point on the earth's crust. An uplift curve can be obtained from the emergence curve by taking into account the eustatic changes of sea level that have occurred.

## GENERAL DESCRIPTION

Inugsuin Fiord lies on the east coast of Baffin Island and extends inland toward the southwest for about 100 km (Figure 1); the locality under consideration is at the head of the fiord.

The fiord occupies a typical fiord basin; it has steep sides and is long and narrow. The steepest slopes are found along the middle part of the fiord at the sharp bend, while gentler slopes prevail farther southwest. At the head of the fiord the surrounding mountains rise to between 600 and 1,000 metres except where a valley leads toward a series of lakes farther west (Figure 2). The lower lakes are dammed by a series of terminal moraines lying between the fiord and the second lake. Apart from this, the only substantial area of low-lying land along the inner part of the fiord is at its head where a large drift deposit has been formed under the steep cliffs that rise approximately 1 km south of the present shore.

During the last glaciation, outlet glaciers from the ice sheet to the southwest flowed toward

Baffin Bay along the valleys and fiords that cross the high mountains of the coastal area (Ives and Andrews, 1963). The ice that filled Inugsuin Fiord came from the southwest and the high level lateral moraines and terraces show a uniform slope down toward the northeast. At a later phase, ice movement was largely determined by the local topography, and the last ice stream to reach the inner part of the fiord flowed along the valley that ends at base camp (Figure 2). Several readvances occurred shortly before final deglaciation of the fiord head, and the trend of the lateral moraines shows a re-entrant of the main outlet glacier flowed into the embayment at the end of the fiord. This is significant for the interpretation of the deposits in that locality.

The area surrounding the head of the fiord was deglaciated more than 7,900 years ago (Figure 2 and Table 1) at a time when sea level relative to the land was some 65 metres higher than today.

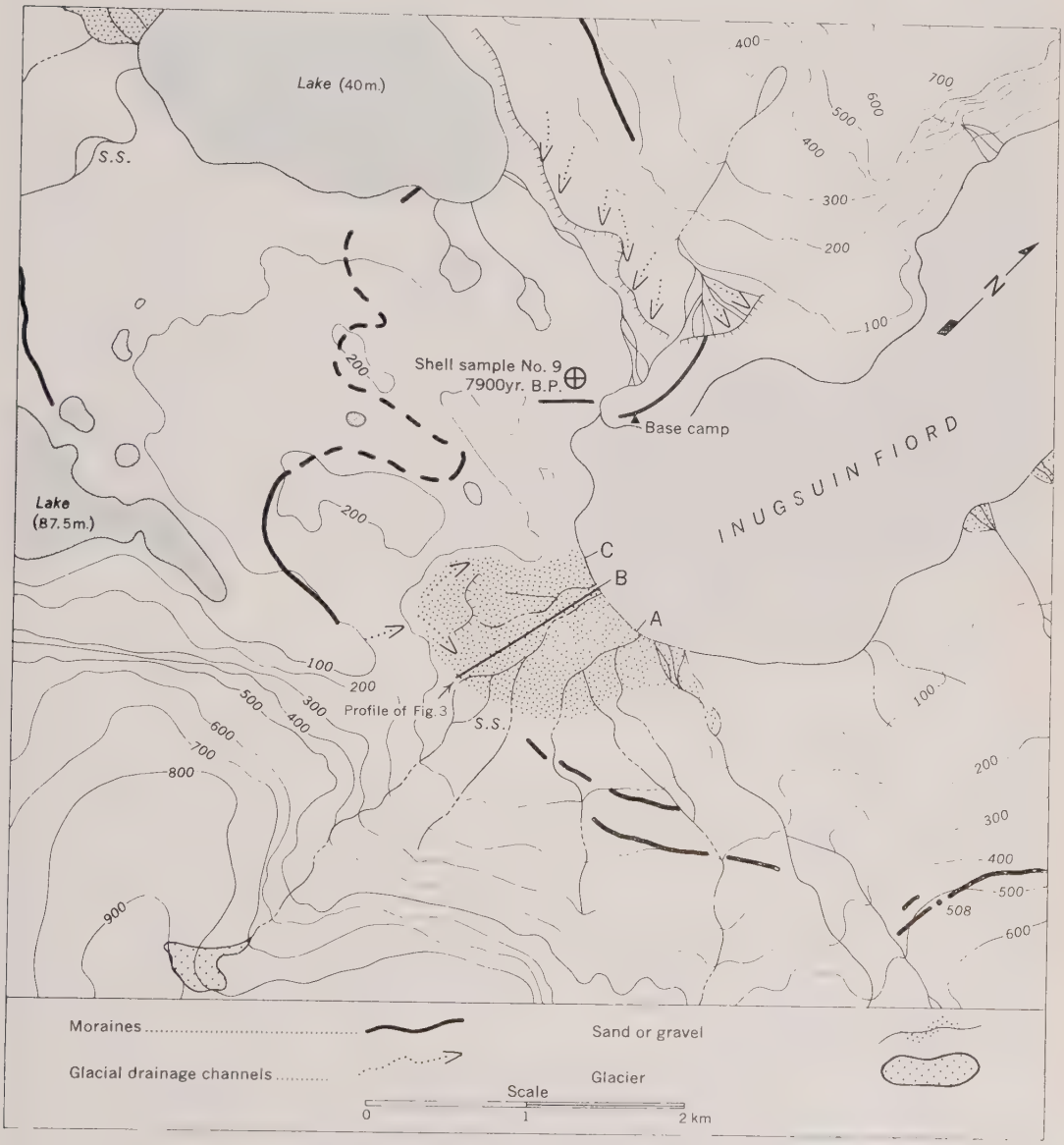


FIGURE 2. Area at head of Inugsuin Fiord.

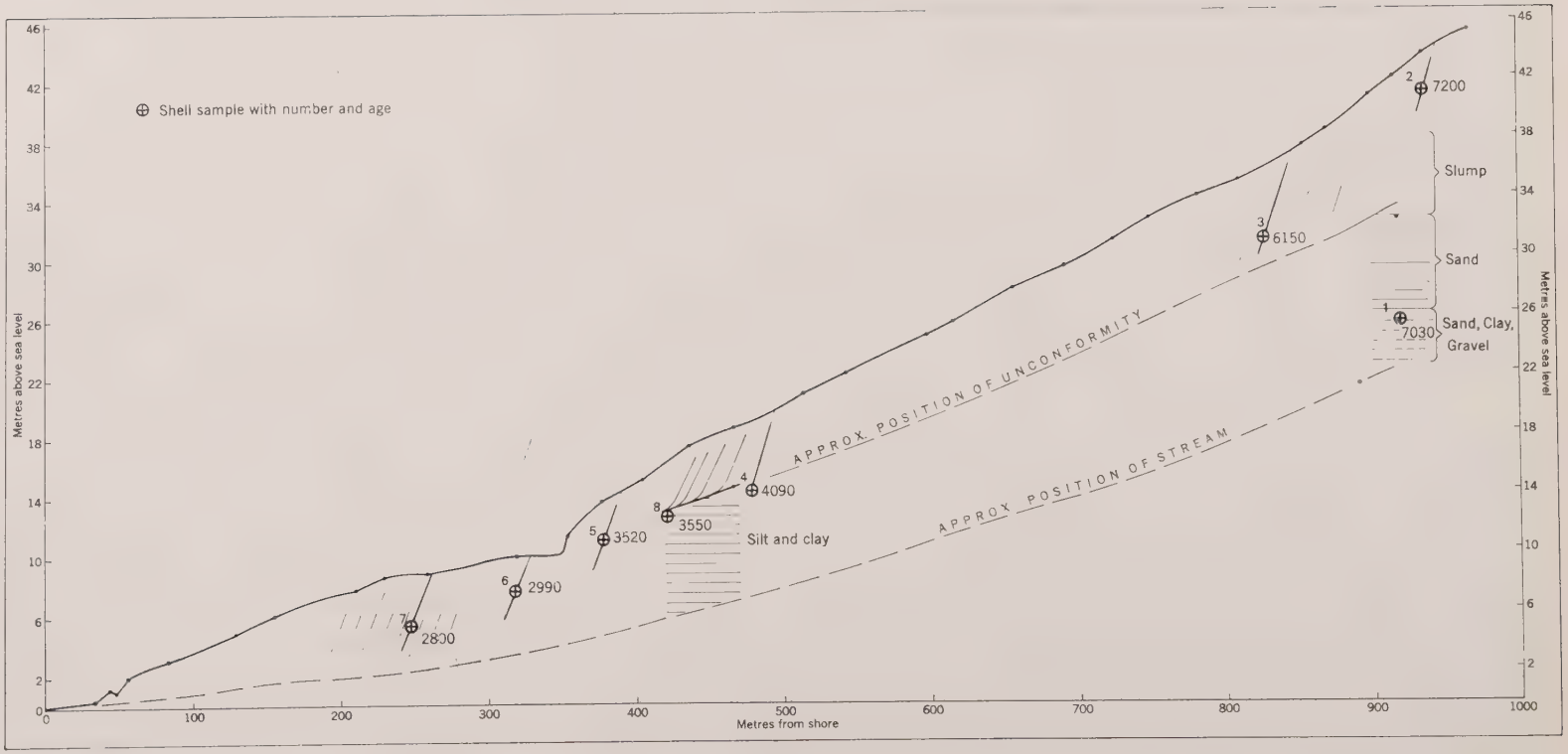


FIGURE 3. Profile of beach deposit, showing stratigraphy and location of shell samples. For location of profile, see Figure 2.

FIGURE 4. The stratigraphy under the highest part of the deposit. Men are collecting shell sample 1.

## THE DEPOSIT AT THE HEAD OF THE FIORD

The drift deposit has the appearance of a gently sloping surface extending from sea level to an altitude of 44 metres over a horizontal distance of approximately 1,000 metres. Detailed study shows the apparently even surface is irregular and numerous ridges, roughly parallel to the present beach and diminishing in size away from it, cross the surface. A profile levelled (by Zeiss N2 level) across the deposit approximately perpendicular to the trend of the ridges is shown in Figure 3.

A stream enters the fiord from the south and has eroded a deep cut in the drift deposit following its emergence above sea level. The cut runs generally parallel to the profile in Figure 3 and exposes the material in steep banks up to 20 metres in height (Figure 4). The material ranges in grain size from gravel to silt and clay, with coarse sand being most common in the upper half of the river bank. At lower levels, silt and clay predominate except in the seaward section where the coarser material extends from the top to the bottom of the profile.

The stratigraphy of the deposit as it is exposed along the river bank is shown in Figure 3. The most conspicuous feature of the profile is a series of seaward-dipping strata each of almost uniform thickness which strike at about 90 degrees to the direction of the profile. The layers, varying in thickness between one and approximately 25 cm consist of well-sorted material varying in size from fine silts to coarse sand or fine gravel. The

dip of the beds is between 18 and 33 degrees, commonly around 24 degrees, and was determined by laying an Abney level or a Brunton compass on the beds. The strata are all but absent from the middle part of the profile, where the slope of the river bank is gentler and covered by vegetation. The permafrost level is high, and it was not possible to make excavations deep enough to expose the actual strata, although their existence can be assumed.

Near the present shore the dipping strata extend from stream level almost to the top of the profile. Farther inland, however, an unconformity separates them from lower, almost flat-lying strata of fine sands, silts and clays. This angular unconformity is accentuated by the change in material and increases in altitude, as shown toward the right of Figure 3. Where the contact is exposed, the lowest 20 cm of the dipping strata become almost horizontal before disappearing.

Figure 3 shows that the dipping strata do not reach the surface of the deposit. In all localities where excavations were made, except near sample 7, the stratification fades toward the top and the uppermost metre shows no stratification. As the distinct stratification disappears, the material becomes poorly sorted.

Well-preserved shells were embedded in many of the layers and samples were collected as indicated in Figure 3. The shells were usually found as complete bi-valves and in only a few cases were the single shells broken prior to excavation. Where occurring in silts and clays, the tubes of some of the shells were preserved.

The altitude and position of the shell samples were determined by T12 theodolite and tachymetry based on known points established along the main profile. The ridges on the surface of the deposit form angles between 80 and 106 degrees with the main profile, and the sample sites shown in Figure 3 have been projected onto the profile along the strike of the ridges.

Terrestrial organic matter was commonly embedded in the sand and silt especially in the strata between samples 4 and 7. Usually the material was scattered among the mineral matter but in some localities, near sample 4 for instance, layers of organic matter one to two cm thick occurred. A sample has been studied by Dr. J. Terasmae of the Geological Survey of Canada, who describes the material as "a detrital accumulation consisting of abundant remains of moss . . . of several species. Small twig fragments of *Ericaceae* and leaf fragments were found . . . but no pollen or diatoms."

Of particular interest are the fossils found under the highest part of the deposit, sample 1. Due to slumping and vegetation the top part of the section through this point could not be observed but it is assumed that it consists of about 7 metres of steeply dipping strata. Below this at least 12 metres of almost flat-lying beds, predominantly of fine sand, are exposed. The lower beds show less uniformity in grain size and several layers of clay occur. At the top of one of them a shell-bearing gravelly layer was found, and sample 1 was collected from it. Unlike the other samples, it consisted mainly of shell fragments and a complete valve was rarely found. Such whole valves were small strong shells of *Hiatella arctica* and in one case of *Chlamys islandicus*. Evidently these shells were deposited under conditions different from those prevailing when the others were laid down. The shells were possibly broken by re-deposition. At the top of the shell-bearing stratum, a large tussock of grass was found. It has been identified as *Puccinellia* (W. G. Dore, personal communication 1965), a species common in the area today. Driftwood was not found in or on the deposit except along the present shore.

On the basis of these observations the feature is interpreted as a littoral deposit that started to form immediately after deglaciation when the horizontal beds (shown at the extreme right of Figure 3) were deposited in relatively deep water. As the land rose relative to sea level, the material became coarser; and the steeply dipping strata of the highest part of the feature were deposited when the land was submerged to about 44 metres above present sea level. With the continuing emergence of the land, stratum was added to stratum and beach ridge to beach ridge at gradually lower levels and the seaward-sloping ruffled surface was formed. The unsorted material immediately below the surface was deposited as beach ridges above sea level, while the dipping beds were deposited in the sea, close to the shore where wave action is less and the long shore current more significant. These strata overlie the silts and clays deposited earlier in deeper but steadily shallowing water. Cryoturbation could have influenced the top part of the deposit, but the well-preserved beach ridges suggest that this process has not been important.

It is assumed that the processes that formed the beach deposit were similar to those active along the present shore. For comparison with past conditions, three profiles A, B and C were surveyed off the present beach to determine the submarine topography. The approximate position of the profiles is shown in Figure 2 and the profiles themselves in Figure 5. The depth soundings were taken by line from a boat and they were located by taking readings with a level to a stadia rod in the boat.

The three profiles are similar in form and consist of three parts. The upper part shows a very gentle slope, the middle part is relatively steep, while a gentler slope prevails in the third and lowest part. The profiles depict a depositional landform, and it can be assumed that this will be preserved during further deposition. Unsorted material will be deposited in the highest parts where wave action is significant. At greater depth better sorted strata conforming to the profile will be deposited under influence of the longshore current.

The same three elements occur in the raised deposit. The steeply dipping strata correspond to the steep middle sections shown in Figure 5; the dip of the beds is comparable. The unsorted, unstratified coarser material of the surface layer shown in Figure 3 corresponds to the upper section close to the shore. Here the greater energy of the waves provides for the greater variation in grain size while more constant forces act at greater depths. Finally, the lowest parts of profiles A, B, and C correspond to the lower flat-lying sediments seen in Figure 3. There, in the deepest water, the finest sediments are deposited.

The survey of the offshore zone thus supports the statement about the mode of formation of the drift deposit although the offshore stratigraphy has only been inferred and is not known from core samples or drilling. Furthermore, it is clear from the study of the stratigraphy and the shells themselves that, with the possible exception of sample 1, the shells collected were found in living position as the younger strata have buried the older ones without disturbing them.

The material for the deposit is brought by the steep stream that enters the fiord at its eastern end. The size of the boulders on its bed testifies to the stream's great geomorphic activity; the beach deposit extends up to the south side of this stream, but not beyond. A check of the material along the present beach shows the grain size decreases away from the river mouth, thus indicating transport towards the south. The two streams entering the fiord from the south have supplied less although redeposition of material eroded from the already emerged part of the deposit clearly occurs.

The material is carried southward by the longshore current, driven by the prevailing up-fiord wind. During the summer of 1964, 35 per cent of all wind observations taken at base camp between June 27 and August 25, recorded up-fiord wind. Although the observations cover a short period, eolian features in the area show that northeast is the prevailing wind direction. Furthermore, these observations cover a substantial part of the ice-free period, the season when the littoral processes are most active. Break-up at the head of the fiord takes place in early July, while the date of freeze-up is not known. Mean freeze-up date for the bay at Clyde River is October 15 (Allen, 1964), but the fresher surface water at the fiord head probably freezes earlier.

Given a constant supply of material, the rate of prograding would depend only on the length of the beach over which the material was distributed. The length of the beach does not change significantly with altitude, except in its highest part. The slope of the profile in Figure 3 will depend on the rate of both prograding and land emergence. For a certain rate of emergence the steepness of the profile will increase with a decreasing rate of prograding. Similarly, with a constant rate of prograding the steepness of the profile will increase with an increasing rate of emergence. Any break of slope on the profile in Figure 3, therefore, indicates (1) a change in the rate of supply of material, (2) a change in the rate of emergence or (3) a change in both factors.

The upper part of the profile is steeper despite a shorter length of beach at this than at any later stage. The short beach length should indicate the prograding would have been faster at that time than later, and should result in a gentle slope. Thus, the steep slope could be created only by assuming very rapid emergence shortly after deglaciation (*see* below).

The most significant break of slope occurs at an altitude of about 9 metres, where the profile is very gentle. This can be explained by assuming a great increase in the amount of material supplied to the beach, with a constant rate of emergence or, alternatively, by assuming a constant supply of material and a virtual halt

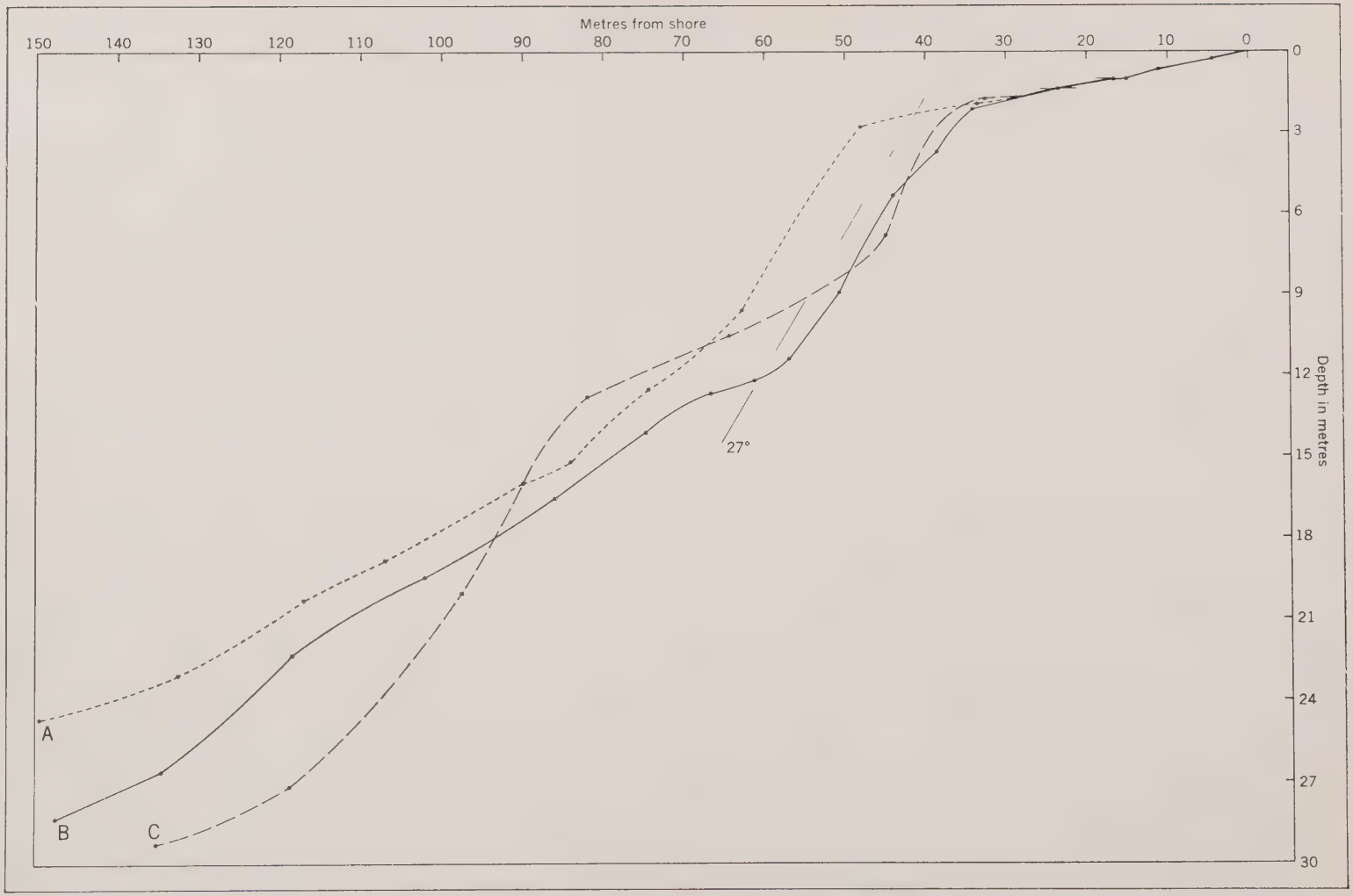


FIGURE 5. Profiles of the offshore zone. For location of profiles, see Figure 2.

in the postglacial emergence. (The latter implies there was no vertical displacement of the shoreline.) It is worth noting that following the irregularity at an altitude of 9 metres, "normal conditions" were re-established, and it is therefore very doubtful if the change can be ascribed to any variation in the supply of material. Support for this conclusion was found in inner Sam Ford Fiord where similar although smaller breaks of slope were observed at approximately the same altitude. The geomorphological evidence seems to imply that a temporary halt in the land emergence occurred when sea level relative to the land was approximately 9 metres above present.

The author has shown (1962) that a postglacial transgression is associated with a strandline in northern Labrador; he suggested that evidence of the same distinct sea level occurs in other parts of the eastern Arctic. It was further suggested that this transgression was contemporaneous with one of the Tapes transgressions in Scandinavia. The almost horizontal part of the deposit at Inugsuin might correspond to the Labrador strandline.

The preceding paragraphs have emphasized the very gently sloping section at an altitude of 9 metres, but an equally important part of the profile is the steep section immediately above 10 metres.

In this context, the altitude of the unconformity (*see* above) is important. It was measured in three places between samples 4 and 8, and a minimum altitude recorded above sample 1. A suggested trend of the unconformity has been drawn in Figure 3, and its convergence with the surface profile to the left of sample 8 is noteworthy. The unconformity was not seen in the section through sample 6. A significant change in the stratigraphy therefore must take place between these two samples, and the steepening of the surface profile supports this suggestion. The change is considered to be related to the topography on which the beach deposit was formed. Figure 2 shows the lateral and terminal moraine at the head of the fiord and reference has been made to the re-entrant that flowed into the embayment here. The steep part of the profile (Figure 3) is believed to lie at the proximal side of the re-entrant moraine which is associated with the terminal moraine approximately three km northeast of the fiord head.

## THE EMERGENCE CURVE

### *Radiocarbon dates*

In order to study the development of the deposit and the postglacial emergence, eight shell samples were dated. Table 1 lists these and a ninth relevant date. The location and number of each sample are indicated in Figures 2 or 3.

There is an apparent discrepancy between the two oldest samples; sample 1, however, is from the bottom of a section approximately 20 metres deep, whereas sample 2 was collected at the top; there can be little doubt about their relative age. The two radiocarbon dates overlap and do not necessarily contradict this statement. A shell

*Table 1*

*Radiocarbon dates*

| Sample no. | Geog. Br. lab. no. | Altitude of sample (metres) | Isotopes Inc. lab. no. | Age in years | Related sea level (metres above present sea level) |
|---|---|---|---|---|---|
| 1 | OHL–64– 9S | 25.6 | I–1554 | 7030±190 | >44.5 |
| 2 | –14S | 41.0 | I–1598 | 7200±150 | 44.5 |
| 3 | –11S | 31.2 | I–1596 | 6150±170 | 37.0 |
| 4 | –12S | 14.4 | I–1597 | 4090±150 | 19.5 |
| 5 | –18S | 11.1 | I–1600 | 3520±230 | 14.5 |
| 6 | 17S | 7.7 | I–1599 | 2990±140 | 9.0 |
| 7 | –10S | 5.4 | I–1555 | 2800±140 | 8.0 |
| 8 | –21S | 12.8 | I–1601 | 3550±130 | ? |
| 9 | DMB–64– 3S | 32.6 | I–1602 | 7900±210 | >32.6 |

sample collected at base camp (by D. M. Barnett) was found to be 7,900 years old, thus showing that the area was ice-free much earlier than indicated by sample 2. While whole valves made up the bulk of the other samples, sample 1 consisted of small fragments and its condition might have influenced the result of the dating. Another possibility is that old shells from higher levels might have been mixed into sample 2, thus giving an exaggerated age. The whole sample in each case was submitted for dating and all dates are based on the inner 80 per cent of each shell sample. None of the dates has been adjusted for the apparent age of the sea water. As none of the species present would bury more than approximately 30 cm into the bottom sediments (F. J. E. Wagner, personal communication), it is therefore assumed that the age of the shell samples is the age of the layer where they were collected.

The samples from the deposit have been arranged in chronological order of decreasing age according to the mode of formation presented above. Sample 8 cannot be fitted into this relative chronology as it was collected in the fine sediments below the dipping strata.

*Determination of sea level*

In order to establish an emergence curve, it is necessary to relate each dated shell sample to its relevant sea level. This is possible by studying Figure 3.

The existence of the beach deposit shows that considerable accumulation has taken place, and as the land emerged, successive beach ridges have been deposited at gradually decreasing levels. Depending on the rate of emergence and prograding of the shore, abrasion of the top part of the steeply dipping strata might have occurred before emergence. Figure 5 shows that the average slope, approximately 4.5:100 is gentler than the shore profile immediately below high tide level which has a slope of approximately 6:100. Providing the average height of the beach ridges has not changed, this is evidence that the prograding has proceeded faster than the rise of the land and no abrasion of the steep strata has taken place except during storms.

During periods of exceptionally intense wave action, abrasion in the littoral zone extends to greater depths and parts of the dipping strata may disappear. When "normal" wave conditions are restored, prograding continues and any "scars" created are covered. Evidence of one such episode was found close to sample 7 where the stratigraphy is as shown in Figure 6. The middle bed was truncated under storm conditions and later covered by the younger layer. As this occurrence was unique, it may be concluded that abrasion of the strata was not common. The reason is probably the limited fetch, as approximately 20 km from its head, the fiord makes two sharp bends. Furthermore, it is ice-covered during the winter period when the strongest winds occur.

In order to determine the sea level at which each dipping bed was formed, the strata of Figure 3 were extended upward until they intersected the present surface of the deposit. The level of this intersection is considered as the former sea level. A similar method has been used by Feyling-Hanssen and Olsson (1959-60). The accuracy of the method depends on the slope of the top profile. As seen from Figure 3, the slope is almost constant, and the result is believed to be correct to one metre. Special consideration must be given to the beds of samples 6 and 7 as the surface slope here is much gentler. The sea levels at which these strata were formed were determined by subtracting 1 metre from the altitude of the intersection between the extended strata and the surface. The value of 1 metre is derived from Figure 3 where it will be seen that the present beach ridge rises approximately 1 metre above high tide. In this case also sea level is determined within an accuracy of one metre. It should be noted that the sea level associated with sample 7 is derived in this way, although the locality differs from the others as the dipping strata here extend to the surface of the deposit (*see* above). The implication is that a part of the deposit has been removed thus giving a sea level too low for this sample.

Corresponding dates and altitudes have been plotted in Figure 7, and an emergence curve drawn. The lack of dates from the last 2,800 years should be noted. A constant rate of emergence has been assumed between all points, although additional dates might result in a modified curve. The curve covers the last two-thirds of the postglacial emergence at Inugsuin Fiord; no reliable information is available on the first third.

FIGURE 6. Exposed strata near sample 7. Truncated bed ends at bend near centre of photo.

## DISCUSSION

The curve consists essentially of two sections of constant rate of emergence separated by a sharp break approximately 3,000 years ago. Between 7,200 and 3,000 years ago the land emerged at an average rate of approximately 0.8 metre per century; this was reduced later to approximately 0.3 metre per century. The older section is well documented while no date is available in the last 2,800 years.

The emergence of about 21 metres that occurred prior to 7,200 years ago was completed in a period of more than 700 years as indicated by the date of deglaciation of the fiord head. Thus, the rate of emergence did not exceed 3 metres per century. Although this is a maximum value it can be assumed that the emergence prior to 7,200 years ago, was faster than the more recent emergence. This agrees with the interpretation of the geomorphological evidence.

The bend in the curve appears at the same altitude as the notch on Figure 3, but the curve shows no indication of a halt in the emergence as suggested on the basis of geomorphological evidence. However, there are strong indications (*see* above) that sample 7 is associated with a relative sea level higher than 8 metres which would make a section in the curve in Figure 7 horizontal indicating a halt in the emergence.

Table 1 shows that the pause in the emergence took place some 2,900 years ago. This was at the end of the postglacial warm period and it supports the suggestion of Tapes age made above.

The general form of the curve is similar to that of other published curves, with a steep older and a gently sloping younger part. Detailed comparison with other curves is difficult because of great



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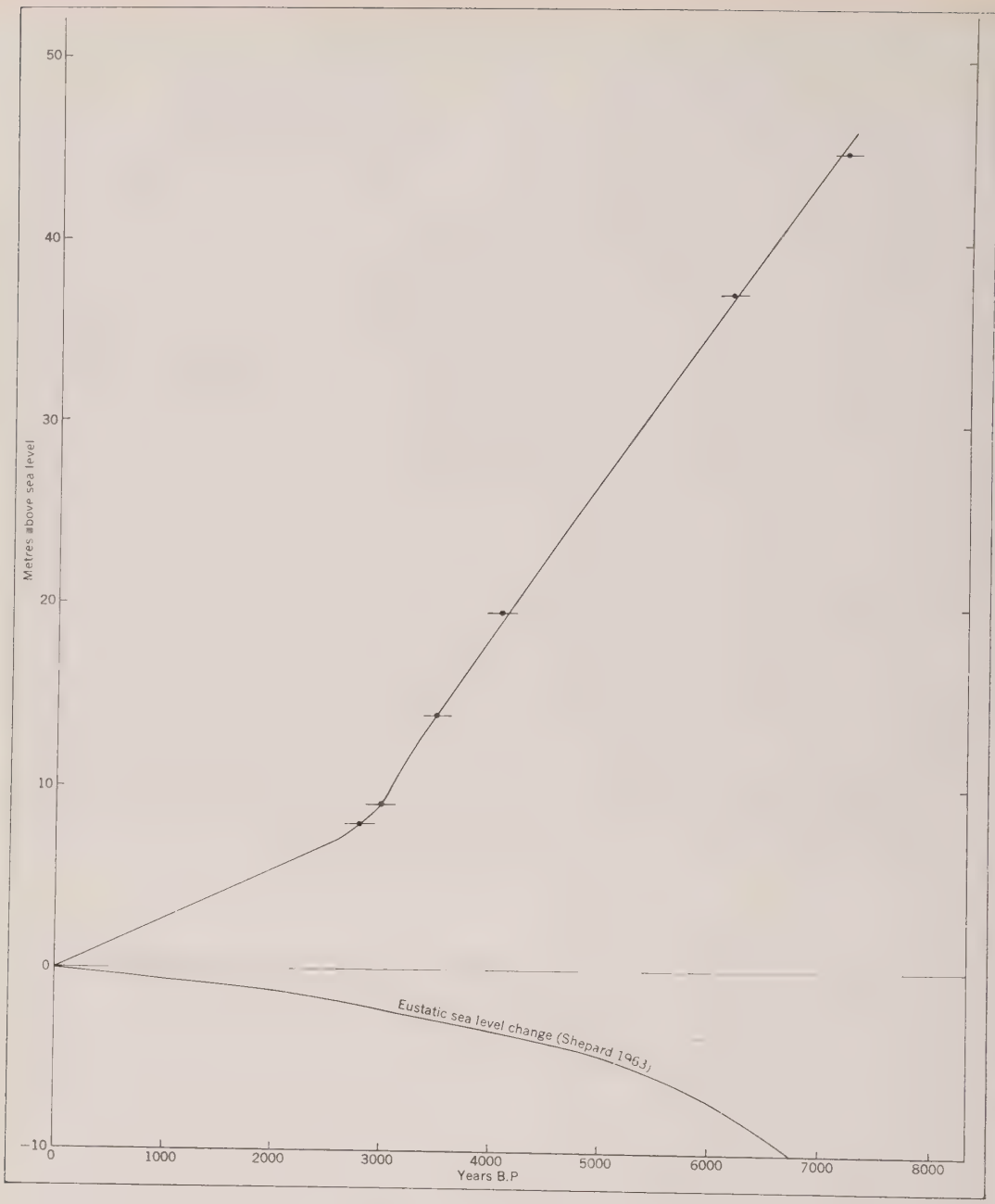


FIGURE 7. The emergence curve.

variations in reliability and differences in glacial history between various localities. A comparison can be made however of the middle third (in terms of total postglacial emergence) of various curves.

On Spitzbergen emergence at an average rate of 2.9 metres per century has been derived from the curve presented by Olsson and Blake (1961-62) and a rate of 2.6 metres per century on the basis of a similar curve published by Feyling-Hanssen and Olsson (1959-60). An emergence curve from East Greenland (Washburn and Stuiver, 1962) shows an average rate of 2.4 metres per century, and Ives' curve (1964, Figure 3) from the west

coast of Baffin Island shows an average rate of emergence of 4 metres per century. It is evident that the Inugsuin uplift was very slow relative to that of other areas.

When the average rate of emergence during the last 3,000 years is considered, the uplift at Inugsuin of approximately 30 cm per century is rapid compared with East Greenland and Spitzbergen where averages of 7 to 17 cm per century have been derived from the published curves. Ives' results from the west coast of Baffin Island, however, show an emergence at an average rate of 50 cm per century in the last 3,000 years.

The difference between the east and west coasts of Baffin Island is significant. On the west coast the oldest shells date from about 6,700 years ago and the period of rapid uplift ended almost 5,000 years ago, that is, in the course of some 2,000 years after deglaciation. At Inugsuin Fiord, the oldest shells are 7,900 years old and the period of rapid uplift was still in progress some 5,000 years later. The accuracy of the uplift curves is not the same, and later results might lead to modifications. The difference, however, is so great that it is doubtful whether any major change will be necessary, especially as the oldest shells on the west coast were collected only 16.5 metres below the marine limit and the chances for finding much older shells are, therefore, small. The reason for this difference is not known but it may be related to the more peripheral positions of the Inugsuin area in relation to the centre of the continental glaciation. Another possibility is the presence of local glaciers along the east coast, while the west coast was influenced only by the continental ice and the Barnes Ice Cap. Further detailed work is needed.

Figure 7 shows only the emergence of the land. To indicate crustal uplift the curve must be adjusted for the eustatic changes. Postglacial eustatic changes are still a matter of controversy, but the curve presented by Shepard (1963) has been plotted on Figure 7, and gives a picture of the adjustments that must be made. An adjusted curve will be similar to the emergence curve in form, but both sections will be steeper.

The change in rate of crustal uplift approximately 3,000 years ago coincides with the transition from the sub-Boreal to the sub-Atlantic period. In early sub-Atlantic time glaciers readvanced in Norway(Liestøl, 1960) and a similar development has been suggested in Canada (Terasmae, 1961). More recently, lichenometric studies by Andrews and Webber (1964) show that a major moraine system around the Barnes Ice Cap is of sub-Atlantic age. Presumably, a readvance of the ice cap would be associated with similar increases of the glaciers along the east coast of Baffin Island. The resulting increased load would retard the crustal uplift that followed the disappearance of the continental ice sheet, whereas the isostatic readjustment on the west coast of Baffin Island would not have been affected by any local ice load. This may explain the difference between the emergence curves.

An interesting fact appears from Table 1; all shell samples except no. 1 were collected at shallow and fairly constant depths of between three and six metres below their related sea level. The samples were always taken where the shells were most abundant and it appears that the ecological conditions for the species involved are most favourable at this depth.

Assuming that the deposit was formed as outlined above, it is possible to make an estimate of the rate of deposition by using the radiocarbon dates and the perpendicular distance between the dated strata. From the currently forming steep bed in the offshore zone to the layer of sample 2, there lies a sediment pack some 750 metres thick. As this has been deposited in the course of 7,200 years, the average rate of deposition has been between 10 and 11 cm per year. This corresponds to an average rate of prograding of 13 cm per year.

## THE FOSSIL EVIDENCE

The shell samples have been examined by Dr. F. J. E. Wagner of the Geological Survey of Canada. The results are summarized in Table II which lists the samples from top to bottom according to increasing relative age.

When collecting the shells efforts were made to obtain representative samples, but obviously many species might have been excluded, giving an incomplete picture of the fauna. However, some information about the ecological conditions can be derived from Table II. This is particularly true when the argument is based mainly on the species which are present rather than on those which are absent. Dr. Wagner remarks that, "These are all shallow water assemblages indicating depths from zero to probably no more than 50 metres. Water temperatures were probably similar to those prevailing in the area at present."



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*Table II*

*Macro Fossils*

| Sample No. | *Mya truncata* Linné | *Hiatella arctica* (Linné) | *Macoma balthica* (Linné) | *Mytilus edulis* Linné | *Clinocardium ciliatum* (Fabricius) | *Chlamys islandicus* (Müller) | *Mya pseudoarenaria* Schlesch | Age in years |
|---|---|---|---|---|---|---|---|---|
| 7 | | X | X | X | | | | 2800±140 |
| 6 | X | C | C | | | | | 2990±140 |
| 5 | R | | C | | | | | 3520±230 |
| 4 | R | R | A | R | | | | 4090±150 |
| 3 | C | R | R | | | | | 6150±170 |
| 2 | X | C | | | R | | | 7200±150 |
| 1 | X | X | | X | X | X | | 7030±190 |
| 8 | X | X | X | X | | | X | 3550±130 |

A – abundant
C – common
R – rare
X – species present—no particular comment made

In northern Canada, only limited work has been done on the mollusc communities of raised beach deposits (*see* however, Wagner, in Craig, 1961 and 1964). The most important attempt to deduce information about past climatic conditions on the basis of such communities is still that of Laursen (1946) who examined the shell collection from northern Baffin Island and the west coast of Foxe Basin made more than two decades earlier by the Fifth Thule Expedition. Emphasis since then has been on the collection of shells for radiocarbon dating in order to determine the date of deglaciation and to assess the postglacial emergence. Little or no consideration has been given to the species collected or to the zoogeographical and ecological significance of the faunal composition. Ellis (1955 and 1960) and Ellis and Wilce (1961) studied the present mollusc fauna of eastern arctic Canada, but the extensive works of Jensen (1905), Laursen (1946 and 1950) and Ockelmann (1958) on the past and present mollusc fauna of Greenland have no parallel in arctic Canada.

Of the species collected in the raised beach deposits at Inugsuin, *Mya truncata*, *Hiatella arctica* and *Clinocardium ciliatum* are widely found in arctic areas today. *Mya pseudoarenaria* and *Macoma balthica* are also common in arctic waters (F. J. E. Wagner, personal communication).

The two most interesting species are *Chlamys islandicus* and *Mytilus edulis*. The former is living in the Disco Bay area of West Greenland (Ellis, 1960) but has not been reported on the west and colder side of Baffin Bay. The species was common in the collections of the Fifth Thule Expedition in samples taken from between 30 and 50 metres above sea level (Laursen, 1946). In the Inugsuin area, the species occurred in sample 7 and also in a sample collected on the proximal side of the large terminal moraine at base camp (Figure 2), at an altitude of 33 metres. The radiocarbon age of this latter sample is 7,900±210 years (Table I). The species has not been found living north of 64°N in eastern Canada (Laursen, 1946) and this suggests that climates warmer than the present prevailed between 7,000 and 8,000 years ago. Laursen's observations are compatible with those made at Inugsuin Fiord where *Chlamys islandicus* appears only in the oldest deposits. This warmer interval falls in the early part of the postglacial warm period and is thus in agreement with the evidence for postglacial climatic change. Why the species occurred only in the earliest part of the warm period and then apparently disappeared is not known.

*Mytilus edulis* lives along the west coast of Greenland as far north as Thule (Ockelmann, 1958) and on the east coast of Baffin Island as far north as Padloping Island at 67°N (Ellis, 1955). At Pond Inlet (approx. 73°N) Ellis and Wilce (1961) and B. G. Craig (personal communication) report accumulation of *Mytilus* shells along the shore. "Some of these contained undecomposed tissues, but attempts to find living colonies were unsuccessful but there is a distinct possibility of

an intertidal population of *M. edulis* in that area" (Ellis and Wilce 1961, p. 233).

*Mytilus edulis* is a common species in the deposit at Inugsuin, and is represented by some remarkably large specimens. A shell from a sea level of 19.5 metres above present was more than 80 mm long. This is larger than any of the specimens reported from Spitzbergen by Feyling-Hanssen (1957), and from West Greenland, Ockelmann (1958) reports only one shell longer than this. It follows, therefore, that this species in the past found very favourable ecological conditions in an area that today is on the fringe of its geographical distribution. This lends further support to the suggested warmer climates in the past.

The common occurrence of *Mytilus edulis* at several levels in the raised deposit is noteworthy because this species has been reported from only a limited number of localities in the Canadian arctic. Washburn (1947) reports *Mytilus edulis* in a raised deposit along the southwest coast of Victoria Island. Farther east Blake (1963) found shells of this species in Bathurst Inlet, and Craig (1961 and 1964) reported it from localities west of Pelly Bay and along the east coast of Boothia Peninsula. Along the shores of the Hudson Strait and Bay, only fragments of *Mytilus edulis* have been found: by the Fifth Thule Expedition at Baker Lake (Laursen, 1946) and in the Belcher Islands–James Bay area (F. J. E. Wagner, personal communication). It thus appears that *Mytilus edulis* in the Canadian arctic has been restricted to the Baffin Bay–Labrador Sea coast south of Lancaster Sound and to the channels immediately to the north of the mainland coast from the Mackenzie Delta area and eastward to Boothia Peninsula.

Laursen (1946) quoted *Astarte montagii* var. *striata* (Leach) as evidence of warmer climates in the past, and the occurrence of this species (F. J. E. Wagner, personal communication) in a sample (OHL–64–15S) collected at Inugsuin Fiord lends further support to the conclusion reached above. The shells were collected at 35.3 metres above sea level, and are stratigraphically slightly younger than the sample dated 7,900 years old. The sub-species has not been reported living in this area or farther north on Baffin Island.

The same species also occurs in a sample collected at an altitude of 30 metres in Ikpik Bay on the west coast of Baffin Island (J. T. Andrews, personal communication). The emergence curve from that area shows that a point at this altitude emerged above sea level some 5,000 years ago, and the shells must predate this event.

The existence of strata of organic material in the beach deposit was referred to above and it was pointed out that they were particularly common between samples 4 and 5 (near the large *Mytilus* shell) and therefore deposited 3,500 to 4,000 years ago. Similar occurrences of twigs and plant material have been found in marine deposits along the west coast of Baffin Island (J. T. Andrews, personal communication) and along the south shore of Hudson Strait (B. Matthews, personal communication). In both cases, the beds were between 3,500 and 4,000 years old. Such accumulations can be explained by assuming an abundant vegetation in the local area, or by a longer ice-free period thus allowing floating matter more time to drift in along the shore. Either explanation requires a more favourable climate.

In summary, the fossil evidence shows that mollusc fauna of the raised beach deposit is not very different from that found in the area at present. The presence of *Chlamys islandicus*, *Mytilus edulis* and *Astarte montagii* var. *striata* (Leach) indicates that ecological conditions have been less severe in the past as two of these species have not been found living in the area; a warmer climate can therefore be inferred.

## ACKNOWLEDGMENTS

The writer is indebted to T. W. Fielding and B. B. Smithson for assistance in the field, and to Dr. F. J. E. Wagner, Geological Survey of Canada, who identified the shells. Dr. W. Blake Jr., Geological Survey of Canada and Drs. J. T. Andrews, M. J. J. Bik and J. D. Ives, Geographical Branch, read the manuscript and contributed many valuable comments.

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# BOOK REVIEW

GEOLOGY AND LANDFORMS AS ILLUSTRATED BY SELECTED CANADIAN TOPOGRAPHIC MAPS. David M. Baird, Geol. Surv. Can. Paper 64-21, 59 p. Price $0.35.

TOPOGRAPHIC MAPS OF CANADA, ILLUSTRATING GEOLOGY AND LANDFORMS. Set of 42 maps selected from the National Topographic System. Surveys and Mapping Branch, Dept. Mines and Tech. Surv. Price $11.50.

On page 8 of the introductory section of his booklet the author explains that, "Because the earth is a slightly modified sphere, any area on it is really flat." This gem of editorial ineptitude, or pre-Copernican astronomy, typifies a publication laudable in its objectives and unfortunate in its execution. The collection of maps and Professor Baird's accompanying booklet have been prepared, "to provide a useful tool to Canadian universities, colleges and secondary schools for teaching physiography and the relationship of geology to land-forms." As this essay in one branch of earth science has been widely announced and therefore its extensive distribution ensured, review in some detail is required, particularly for the benefit of high schools.

A ten-page introductory section describes the National Topographic indexing system, scales used, methods of showing relief, organization of maps and the location of features on maps. The main body of the work allocates one page of description to each map; a paragraph describes the general geology and relief of the map area and is followed by a list of "Landforms of note" and appended references.

The introductory section is straightforward, if somewhat pedantic. Brief explanations of "latitude" and "longitude" could have been more effectively executed with a simple diagram. The army grid system is used on some of the maps but the author does not explain it, and his reluctance to use it for locating features is surprising because ultimately all topographical map sheets produced by the Surveys and Mapping Branch up to a scale of 1:250,000 will have this superior system of co-ordinates. Instead he proposes a simple, if sometimes confusing scheme of his own. Shaded relief is not produced as if the light source were in the northeast, as stated on page 6, but in the northwest. The whole introductory section could have been replaced with a brief description of the final map in the collection.

The main concern of this review is naturally with the descriptions of the maps. A general comment of philosophical import might set the pattern for criticism. The author writes in the Introduction (page 1) about the teaching of "physiography and the relationship of geology to landforms", and on page 18 he points out "rock structures reflecting topography". Are physiography and landforms a part of geology? If so, then the word "geology" should be omitted from the title. These difficulties have probably arisen because a hard rock geologist has attempted to use a series of topographical maps to illustrate landforms, and has ended up by greatly overplaying the hard rock geology and losing the landforms in a confusing brew of geomorphic terms, few of which are defined and some of which seem to be of his own coining. The result is a bewildering mixture of inaccurate descriptions, misapplications and direct misinterpretations. Cirque glaciers are referred to as "alpine glaciers"; hanging valleys become "hanging streams"; "spillways" apparently carved their own channels; "glacial lakes" and "glacially dammed lakes" occur on many map sheets yet there is no example of a true "ice-dammed lake". Peculiar terms creep into the text, such as "pseudo straths" and "pseudo-old-age streams"; still more peculiar as "landforms" are the "square road systems", the "settled farm land", the "railway embankments" and the "frilly contour lines". Another group of features the author emphasizes with specific mention include such self-evident items as: very large lakes, large rivers, islands in rivers, swamps, waterfalls, and other features covered by the standard map legends.

Moraine Lake (map 10) is an example of the unsatisfactory coverage provided many map sheets. In the six lines of general description it is claimed that, "The surface clearly shows the effects of the passage and melting of the continental ice-cap". The melt-phase features are evident but passage of the ice sheet is certainly not. Under "Landforms of note" there are six items, two of which (numerous islands and sparsely wooded area) can be dismissed as fatuous; a third (pseudo-old-age stream) leaves the reviewers mystified and a fourth (recessional moraine) is a misinterpretation. One of the most conspicuous features on the map is the large area occupied by rippled till (Ives, 1956; Hare, 1959; Hughes, 1964); some of the ridges of this sub-glacial till pattern appear to have been interpreted by the author as "recessional moraine". If the commentary provided covered all that could be read from this example, then the Moraine Lake map sheet should have been omitted; a casual glance, however, reveals the existence of rippled till (mentioned above), an esker with associated kettle holes and sand spits.

The St-Clair Flats sheet (map 19) is another example of inadequate treatment. Three of the six "landforms of note" are: large river, frilly contour line and rectangular and square road systems. The other three are repetitious parts of the crow's foot delta.

In the description of the Montreal sheet there is reference to the "plain" but no mention of the St. Lawrence Lowland, a correct regional designation; there is reference to the erosional remnants above the plain but not to the fact that these are widely known as the Monteregian Hills.

Why, when there was so much space available, did the author indulge in such brevity, for instance, with the Beloeil sheet. A second year geography undergraduate of McGill University would be expected to supply at least a thousand words of good description and interpretation. If the author had followed his own advice on the interpretation of contour lines he would have discovered that the small lake on Mont St. Hilaire is set well within the mountain and is certainly not on the top.

The provisional map of the Mackenzie Delta area (map 38) receives the sparsest treatment of all and carries no references. (The selection of references throughout the text is interesting; it is entirely restricted to publications of geologists, and of these the overwhelming majority are by the Geological Survey of Canada.) Yet this area is extremely well known through more than 10 years of field research by J. R. Mackay, one of whose more significant publications provides an excellent account of the landscape of the area (Mackay, 1964). It is hardly conceivable that descriptions of parts of the southern Ontario landscape should carry no reference to the outstanding work by Chapman and Putnam (1951). The very word "landscape", so important to the geomorphologist, was not found by these reviewers anywhere in the text; the lack of a "feel for landscape" characterizes the entire work. The hard rock geology is frequently covered in fair detail and, to these reviewers, is developed to a degree beyond the scope of the high school where "physical geography" is taught rather than hard rock geology and tectonics. In detail much of the geological description is irrelevant, as the migmatites and the metasediments are frequently buried beneath a thick mantle of glacial drift, and have no influence whatsoever upon the topography. In brief, what was required was less geology and more landforms, perhaps fewer maps and more detailed and accurate treatment of those retained. As an example of this alternative approach, and as a comparison to the author's treatment of Map 11 (Hamilton, Ontario) Miss Edwards provides the following brief essay; she has broadened the approach to embrace a short description of the main cultural features which we believe would make a publication of this nature more useful.

The landscape of the Hamilton map sheet can be divided into three main elements. Most prominent is the Niagara Escarpment that trends north-south and roughly bisects the area. Above the escarpment the countryside is gently rolling and has a local relief of approximately 300 feet. Below the escarpment the land slopes gradually southeastward to the shoreline of Lake Ontario. The highest land lies in the extreme northwest and reaches almost 1,100 feet above sea level, giving a maximum relief of slightly more than 830 feet from the lake level. Upon this basic physique, controlled closely by gently dipping sedimentary rocks of Ordovician and Silurian age, are found the myriad minor landforms largely associated with the glacial and post-glacial history of the area.

The face of the Niagara Escarpment consists of Silurian shales, limestones and sandstones, capped by the resistant, 100-foot thick Lockport dolomite. The soft red Queenston shale of Ordovician age forms the footslope; it is highly susceptible to weathering as evidenced by the severe gullying to the southeast of Waterdown.

The general north-south trend of the escarpment is broken in the extreme south by the large pre-glacial

Dundas valley and in the north by another valley between Mount Nemo and Rattlesnake Point (Karrow, 1963, p. 10). Both valleys are now partly filled with glacial material, chiefly till, into which the modern streams have cut. A small section of the Lockport dolomite northwest from Rattlesnake Point has been severed from the main escarpment to form a cliffed outlier.

Glacial till covers most of the area east of the escarpment and forms the surface material immediately west of it. Part of the Trafalgar moraine is marked in the extreme northeast by the closed 600-foot contours lying southeast of Base Line Road; it extends through Zimmerman beyond which it merges into the base of the escarpment. On the crest of the escarpment the Waterdown moraine extends from Mount Nemo to Waterdown; southwest of Waterdown it breaks into several branches. The moraine is delineated north of Waterdown by the smooth oblong contours between 800 and 950 feet. Southwestward to Dundas the 700- to 800-foot contours outline the two main branches which are separated by the small Rock Chapel Creek.

Sands and shallow lacustrine deposits occupy the area adjacent to Lake Ontario and most of East and West Flamborough townships above the escarpment (Karrow, 1963, Map 2033). Several drumlins rise above the sand plain southeast of Carlisle. On the east-facing slope of the escarpment, drift mantling the Queenston shale has inhibited the severe gullying so conspicuous further southwestward.

Lake Iroquois, which existed during late-glacial time, has left a number of prominent lacustrine features in the southern part of the area. The most striking is the gravel bar separating Cootes Paradise from Hamilton Harbour. The bar rises approximately 80 feet above the present lake level, and gives evidence of the former high level of Lake Iroquois in this area. The broad flat area between the 325- and 350-foot contours southwest of Aldershot is the top of a gravel spit formed in association with the bar. The spit is responsible for the diversion to the southwest of Grindstone and neighbouring creeks. The modern counterpart of the Iroquois bar is the Burlington bar separating Hamilton Harbour from the main lake.

The Lake Iroquois shoreline is generally difficult to find because of the contour interval: it approximates the 350-foot contour eastward from Dundas and rises to 375 feet northeast of Aldershot; further northeast still it approaches 400 feet. This increase in height of the shoreline is the result of differential tilt of the land following withdrawal of the last ice sheet.

The irregular terrain west of Dundas is a reflection of till deposits in the Dundas valley; the town itself stands on a relatively level area that is the top of a deltaic deposit laid down by Spencer Creek into the former Lake Iroquois.

Upstream from Zimmerman, Bronte Creek has laid down a small flood plain; a rock outcrop south of Zimmerman controls the down-cutting action of the creek above this point. Oakville Creek in the northeast has a well developed flood plain as far upstream as Glenochry. During a low stage of Lake Iroquois these southeast-flowing streams were cutting to a base-level below the present Lake Ontario shoreline; subsequent rise in lake level affected the down-cutting process and small flood plains began to form.

*Cultural features*

The most notable indication of human occupance is the city of Hamilton which occupies the Lake Iroquois sand plain south and southwest of Hamilton Harbour. Urban expansion has occurred along this plain north of the Harbour, in contrast to the areas of dissected Queenston shale north of Aldershot and the swampy and dissected areas of Cootes Paradise and northward to the escarpment.

The transportation network, especially in the south, has been closely controlled by the main elements of the relief; the Dundas valley break in the escarpment is particularly significant. Spectacular use has been made of the two bay-mouth bars as major north-south routes across the water barrier of Lake Ontario; the outer bar forms a major natural harbour wall and has influenced the location of the Hamilton water front facilities.

The smooth dry site of Dundas was settled before Hamilton; part of the city has been built on land that was formerly swampy. The now abandoned Desjardins Canal through Cootes Paradise was cut through the Iroquois bar to provide access to Hamilton Harbour from Dundas, With the subsequent development of Hamilton, Dundas declined in importance and the canal fell into disuse.

In conclusion there remains the criticism of the mechanics of production. The editing and presentation leave much to be desired; misspellings, repetitions, ungrammatical sentences, poor phraseology, changes in print size from one page to the next, are characteristic. It is sometimes difficult to distinguish the editorial mistakes from the original inaccuracies. Many items in the index are not referred to in the text and *vice versa*. The maps in the folio are not numbered and it is difficult to work back from the maps to the text. Most disappointing of all, there is no map showing the broad physiographic regions of Canada; this would have been a major asset, if not an essential part of such a publication.

The author should have made it clear, particularly for the benefit of high school teachers and

junior university students, that the 'descriptions' presented are not 'interpretations' based entirely on data provided by the maps themselves. The booklet will probably confuse many high school teachers and runs the risk of hindering rather than assisting the teaching of "physiography".

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(Theo L. Hills and Karen Edwards)

# GEOGRAPHICAL BULLETIN

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